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Original Communications

DORSAL SYMPATHETIC GANGLIONECTOMY FOR INTRACTABLE ASTHMA

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At the beginning of any discussion of bronchial asthma it must be admitted that the pathologic physiology of the asthmatic attack is variable and that many factors probably combine to produce the symptom complex known as asthma. Surgery of the autonomic nervous system for bronchial asthma at present consists of the excision of organs whose function is partially known for a disease the cause of which is not fully understood.

It is the purpose of this paper to touch upon the high spots of known fact and conjecture concerning this syndrome called bronchial asthma and to describe an operation which promises to relieve some of the patients suffering with it while more fundamental researches are being carried on.

Reduction of the bronchial lumen appears definitely to be the modus operandi of asthma. It has been observed by all who use the bronchoscope on asthmatic patients and has been repeatedly observed in bronchograms with iodized oil. However, in our experience these "contracted" bronchi are regularly found in asthmatic patients *between attacks,* leading us to believe that perhaps the bronchi do not contract and relax in response to stimuli from the extrinsic nerves, as has long been supposed. In certain patients, at least, we have shown that the bronchi of all diameters are in a constant state of diminished caliber and that the asthmatic attack depends upon the changing state of *the bronchial mucous membrane and bronchial secretions.*

The only evidence we have found to indicate that contraction takes place is the observation of Huber and Koessler[1] that some patients with a history of asthma show hypertrophy of the smooth bronchial muscles after death. Hudson and Jarre[2] have demonstrated this chronic reduction of the bronchial lumen

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Originally read before the American Association for Thoracic Surgery at Los Angeles in 1939. Additional observations made upon the original patients and case histories of two more recently operated patients have been added. Publication, formerly withheld because of the small series and relatively brief follow up, now appears justified.

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with iodized oil and the Cin-ex camera, making serial x-ray films in quick succession. Further evidence of the constant nature of the contraction is found in the fact that patients relieved of asthmatic symptoms still show the reduced bronchial lumina. Relief obtained by some patients from irradiation can best be explained by its effect upon the bronchial mucosa.

Lukens[3] describes four types of change in the bronchial mucosa of asthmatic patients; one, a septic tracheobronchitis with abundant mucopurulent secretions adherent to the mucous membrane; two, a chronic catarrhal tracheobronchitis with intensely inflamed mucosa and with a small amount of mucopurulent secretion; three, a cyanotic and swollen mucosa of the trachea and bronchi; and, four, a mucosa with actual urticarial patches. Christopherson[4] describes a condition occasionally observed by us in which the tracheal and bronchial walls have become collapsible so that during forced expiration or coughing a mere slit is presented for the escape of air.

Phillips[5] believes that some metabolic or systemic disturbance conditions the patient to render him susceptible to stimuli in the mouth, nose, throat, ear, or lower air passages, those "trigger areas" supplied by the fifth, ninth, and tenth cranial nerves. The susceptible patient shows an asthmatic response to stimulation of one or more of these areas, whereas the normal individual does not. In support of his belief Phillips reports that a large group of his asthmatic patients shows a low average temperature, a low or low normal metabolic rate, low blood pressure, low blood sugar, high gastric acid level, low urea nitrogen, and high indican level in the urine, and, frequently, a dry, thick or eczematoid skin subject to discolorations. Godard[6] also has noted the low and unstable blood calcium level in his patients with asthma.

The sympathetic ganglia removed by us at operation from asthmatic patients showed histologic evidence of toxic or metabolic degeneration.

All authors agree that the extrinsic nerve supply of the lungs is derived from the vagus and sympathetic trunks from which fibers combine on the posterior surface of the hilum to form the posterior pulmonary plexus. Danielopolu[7] believes that a simple bronchomotor reflex arc exists through the sympathetic (afferent) and vagal (efferent) pathways because "identical results (are) obtained by sectioning two nerves which contain antagonistic bronchomotor fibers." Phillips and Scott[8] state that "much opinion and little fact is presented to prove that the sympathetic is the afferent and the vagus the efferent trunk of a reflex arc." Kummell[9] believes that bronchial constrictor fibers run in both the sympathetic and vagal trunks, the basis for his original cervical sympathectomy for asthma. Levin[10] believes that bronchial constrictor fibers are contained in the sympathetic trunk and describes the pathway through which the sympathetic fibers distributed to the pulmonary plexus by the cervical sympathetics arise in the thoracic segments, showing that the whole bronchial sympathetic innervation is derived from a thoracic source. He observes that vagus manipulations in operations upon the esophagus slow the heart but produce no asthma, and that lesions of the vagus, paralytic or irritative, are not characterized by asthma. Carmichael and Fraser[11] have demonstrated the release of acetylcholine (a depressor and relaxor) about the nerve endings of the vagus on stimulation, and a substance like adrenin on stimulation of the sympathetic nerves. These observations make it difficult to believe that the vagus is a simple bronchial constrictor. What seems more likely true from the evidence of the several authors is that the vagus and sympathetic trunks contain both sensory and motor fibers and that normal bronchial tone (or normal function of the mucosa and glands) depends upon a balance between them.

Freeman, Smithwick, and White[12] state that "structures which receive their nerve supply from the sympathetic nervous system become more sensitive to adrenin after denervation," as was demonstrated by their work upon the blood vessels of the extremities. Adrenin applied directly to the bronchial mucosa shrinks the membrane and reduces secretions. Applied directly to the smooth muscle it would be expected to produce contraction rather than relaxation. If the bronchial lumina are in a constant state of reduction due to muscle spasm or other cause, sensitization of the mucosa to the patient's own adrenin is a possible explanation for the beneficial effects of sympathetic denervation.

Levin supports his views with a series of twenty-three patients whose dorsal sympathetic ganglia he destroyed by alcohol injections. Complete relief from asthmatic symptoms was obtained in 75 per cent of his patients, with varying degrees of improvement in the remainder. Either sufficient bronchomotor fibers were destroyed to alleviate symptoms or the mucosa and glands were favorably influenced.

Complete denervation of the lung by excision of the posterior pulmonary plexus is unquestionably the most certain method now known for eliminating all extrinsic nerve stimuli. Rienhoff and Gay,[13, 15] report excellent results with this operation in twenty-six cases. However, these patients are frequently very poor operative risks with marked limitation of cardiorespiratory reserve. We feel that a procedure requiring less drastic surgery is to be preferred if comparable results can be obtained. It is also an ideal in surgery to preserve as much normal function as possible while achieving the desired result. For these reasons the apparent logic of Levin's article appealed to us and it was decided to perform a bilateral dorsal sympathetic ganglionectomy upon two patients and to observe the results before proceeding with the operation upon others. The apparent success obtained with the first two patients encouraged us to perform the operation upon the third a year later.

TECHNIQUE OF OPERATION

The first two operations (the right side of each of the first two patients) were performed according to the technique of Adson and Brown,[14] exposing part of the fourth rib and its transverse process after separating the erector spinae muscles from the dorsal processes of the vertebrae. After resecting the transverse process and about one inch of the rib, the sympathetic trunk was engaged with a nerve hook and brought into view. The third and fourth ganglia were resected. The ganglia lie on the anteromesial surface of the heads of the ribs and are, therefore, not immediately seen from this posterior approach. The field entered is also a very vascular one. We felt that the normal approach of the thoracic surgeon would simplify the procedure.

In the next four operations a crescent-shaped parascapular incision was used, resecting the third and fourth ribs to a point two inches lateral to their angles. The transverse processes were also removed. The cleavage plane external to the endothoracic fascia was developed, pushing the pleura and fascia away from the heads of the ribs. The sympathetic ganglia could then be clearly seen, dissected free of all connecting rami, and excised with the intervening sympathetic trunk. The wound was closed in layers without drainage in all cases. For us the operation was technically much easier to perform and more satisfactory from the standpoint of exposure.

The last four operations were performed similarly except that the second, third, fourth, and fifth dorsal sympathetic ganglia were removed.

CASE REPORTS

Case 1.— F. I., a Negro woman, aged 25 years, unattached, entered the John Gaston (City) Hospital Nov. 26, 1935, stating that in 1928 she began to have attacks of wheezing and dyspnea occurring each fall. By 1935 the wheezing was almost continuous, with freedom from symptoms never lasting over a week. No particular food or plant allergies were noted. During five admissions to the hospital and innumerable visits to the emergency room she received treatment with adrenalin, ephedrine, morphine, atropine, pituitrin, potassium iodide, magnesium sulphate, and calcium gluconate. Gradually all forms of medication failed to bring relief. An attempt to isolate the patient from allergenic proteins failed to affect her condition. The patient claimed she had been unable to work since 1928.

Past history was negative except for a Caesarean section and antisyphilitic treatment in 1928.

The family history was negative for tuberculosis, cancer, or evidences of allergy.

Physical examination revealed an old-looking Negro woman sitting up and inclining forward, struggling for breath. All of the accessory muscles of respiration were active. The chest was barrel-shaped and hyperresonant, and auscultation revealed typical râles, rhonchi, and siffles of bronchial asthma. The remainder of the physical examination was of no especial interest. None of the abnormalities of the upper air passages frequently associated with asthma were discovered by the Nose and Throat Service.

The blood picture was normal except for an eosinophilia up to 6 per cent. The Kahn test was negative. Sputum was negative for tubercle bacilli on numerous occasions, but Curschmann's spirals were frequently seen. Stereoscopic x-ray films of the chest before operation revealed a moderate bilateral emphysema, but no parenchymal pathology.

A bronchoscopic examination Dec. 2, 1935, revealed no foreign body, tumor, or other mechanical obstruction.

On Dec. 4, 1935, a right dorsal sympathetic ganglionectomy was performed by the technique of Adson and Brown, removing about one inch of the fourth rib with its transverse process. The sympathetic trunk was severed above the third dorsal ganglion and below the fourth, and the intervening ganglia and sympathetic trunk were removed.

The postoperative course was uneventful and the patient was discharged eight days after operation, having experienced a few slight attacks of dyspnea which were relieved by ephedrine ¾ grain by mouth.

Attacks of asthma continued to occur on the average of about once a month. The patient, discouraged because total relief was not obtained, refused the contralateral operation until September, 1937.

On Sept. 16, 1937, a left dorsal sympathetic ganglionectomy was performed, employing the revised technique described. The pleura was accidentally torn, admitting air which was controlled with a pack until the completion of the operation and an airtight closure of the muscles without drainage could be performed.

Microscopic Examination.—"Section from ganglions reveal the ganglion cells to be moderately atrophic with small nuclei in which nucleoli are not visible and in which many nuclei themselves are invisible. Cytoplasm was faint-staining.

"Diagnosis: Ganglia with focal atrophy of ganglion cells." [L. C. Harris, M.D.]

The postoperative convalescence following aspiration of the pneumothorax was uneventful. The patient had two mild attacks of dyspnea which were entirely subjective, and which were promptly controlled with ephedrine, ¾ grain by mouth. No wheezing could be made out on examination but a little bronchial moisture could be heard. The patient was discharged on the twelfth postoperative day greatly improved.

The patient obtained a job as ward maid in the Baptist Memorial Hospital where she worked continuously for two years.

On June 26, 1939, a check-up examination revealed that the patient had gained 63 pounds in weight. She had had no true asthma attacks since the first month after her second-stage operation. She occasionally felt "choked up" when working in a hot and stuffy place, but these symptoms were relieved by either leaving the room or taking an ephedrine capsule. No abnormal signs could be heard on physical examination of the chest. The patient stated that she had not lost a day of work because of asthma since she obtained her job nineteen months previously.

A check-up interview in September, 1946, revealed that the patient had taken a course in nursing at Meharry University, had gained 100 pounds, and was working regularly as a registered nurse. The patient stated that she occasionally "chokes up," especially on taking cold. During these periods she receives an injection of a few minims of adrenalin or takes ⅜ grain of ephedrine by mouth as often as twice daily. Much of the time no medication is required.

Relatives report in May, 1947, that the patient is working in St. Louis and is "fat and fine and we done saved her life."

CASE 2.—E. S., a Negro woman, aged 32 years, married, entered the hospital Dec. 1, 1935, stating that she had suffered from asthmatic attacks for seventeen years. At first these attacks were seasonal, occurring particularly in the summer and fall, but since 1932 the attacks had been almost constant, especially since the removal of nasal polyps.

The past history revealed antisyphilitic treatment twelve years previously, unsuccessful attempts to treat severe pyorrhea and to control caries of the teeth, constipation, and the "whites" for many years. The patient had suffered several attacks of so-called pneumonia.

Physical examination showed an orthopneic Negro female in respiratory distress. Nasal polyps and dental caries were present. The chest was barrel-shaped and auscultation revealed the typical râles, rhonchi, and sibilles of bronchial asthma. There was marked clubbing of the fingers.

The blood picture was normal except for an eosinophilia of 2 to 18 per cent. The Kahn test was negative. The sputum showed Curschmann's spirals on all examinations, and eosinophiles in some specimens. No tubercle bacilli were found. Stereoscopic x-ray films of the chest revealed a marked bilateral emphysema, thickening of the vascular lung markings, but no parenchymal disease.

Bronchoscopic examination Dec. 4, 1935, revealed the upper trachea deflected to the right, but with no marked angulation. No foreign body, tumor, or other mechanical obstruction was found. Much glarey mucous was removed by aspiration.

On Dec. 11, 1935, with 0.5 per cent procaine anesthesia, a right dorsal sympathetic ganglionectomy by the technique of Adson and Brown was performed.

The following day the patient developed a total atelectasis of the left lower lobe which was controlled with carbon-dioxide and oxygen inhalations, ammonium chloride, and postural drainage. The convalescence was otherwise uneventful and the patient was discharged on the seventeenth postoperative day having had no further attacks of asthma.

In a few weeks the patient again began having occasional attacks of asthma, but less frequently and with less severity than before the operation. On only one occasion was the patient admitted to the hospital for medical treatment. This patient was so encouraged by the results of the first operation that she refused the contralateral operation. In January, 1936, she had an attack of lobar pneumonia in the right upper lobe, pneumococcus Type IV, which resolved by lysis. Stereoscopic x-ray films before discharge fourteen days later showed complete resolution.

The patient was persuaded to return for the contralateral operation and on Sept. 14, 1937, the left third and fourth dorsal sympathetic ganglia were resected by the revised technique.

The postoperative course was extremely smooth. The patient had a slight constant wheeze for which no medication was required. Discharge from the hospital occurred on the twelfth postoperative day.

Beginning about two weeks after her discharge from the hospital the patient began again having severe paroxysms of dyspnea which were worse than those in the interval between operations. These continued frequently and severely for another six weeks, then they began to disappear gradually. Four months after operation the patient obtained a job as house maid and worked continuously for three months. Since then she has been doing housecleaning work by the day.

At check-up examination on May 10, 1947, the patient states that she feels better than she ever has in her life. She weighs 140 pounds, an estimated gain of thirty-two pounds in the past ten years. She does day work and has lost no time in the past three years because of her health.

The patient admits that she occasionally feels an attack of asthma coming on and that her favorite treatment is to "drink a little whiskey," which usually averts the paroxysm. On two occasions, in spite of liberal self-treatment, aminophylline has been required for relief.

It is the opinion of the authors that this patient has no true asthmatic attacks, but becomes worried when the chest begins to feel tight from her residual emphysema and bronchitis.

CASE 3.—J. W., a Negro boy aged 13 years, entered the hospital Oct. 19, 1938 complaining of severe attacks of asthma for about nine years. The paroxysms were not seasonal and had been increasing in frequency and intensity until they were almost continuous. The patient had lost sixteen pounds in the previous nine months and had been completely out of school for a year.

The past history was negative except for measles, mumps, and pertussis in early childhood.

The family history revealed the patient's father and one aunt with asthma. All other close relatives were living and well.

Physical examination showed a fairly well-developed but poorly nourished Negro boy. The chest was barrel-shaped and auscultation revealed marked inspiratory and expiratory rhonchi, sifles and musical râles. Physical examination was otherwise negative.

Blood examination showed 6,000,000 red blood cells, 16 Gm. of hemoglobin and a normal total white cell count. In the differential white cell count were 2 basophiles, 34 per cent eosinophiles. The blood Kahn was negative. Sputum examinations were negative for tuberculosis, but revealed large numbers of Curschmann's spirals.

Stereoscopic x-ray films revealed congested vascular lung markings with slight emphysema in both lower lobes. No evidence of parenchymal pathology was seen.

Bronchoscopy on Oct. 20, 1938, showed the tracheal and bronchial mucosa normal, the secondary bronchi were slightly narrowed and contained much frothy mucoid exudate. No foreign bodies, tumors, or other obstructions were seen.

On Oct. 27, 1939, a left dorsal sympathetic ganglionectomy was performed, removing the third and fourth sympathetic ganglia in the manner previously described.

Microscopic Examination.—Sections are from ganglion. Ganglion cells reveal some autolytic changes. The interstitial cells may be slightly increased. The surrounding connective tissue is dense and fibrous in some regions.

"Diagnosis: Slight fibrosis of ganglion." [Dr. W. W. Brandes]

Convalescence from the first operation was uneventful and the patient suffered no attacks of asthma. (It is to be remembered that during the early postoperative days the patient received adequate sedation with morphine to relieve pain, which may account for the absence of paroxysms.)

On Nov. 10, 1938, two weeks after the first operation, a right dorsal sympathetic ganglionectomy was performed under ethylene anesthesia, using the revised technique.

Microscopic Examination.—". . . the ganglion cells are intermingled with nerve fibers and in one portion of the ganglion there is a slight suggestion of increased cellularity. The connective tissue surrounding the ganglion is slightly increased.

"Diagnosis: Nerve ganglion with mild ganglionitis." [Dr. T. M. Dunn]

The patient's immediate postoperative course was uneventful until the third day when he began to have asthmatic attacks again. These were not severe and were easily controlled with 10 minims of adrenalin. However, he continued to have one or two a day until his discharge from the hospital and repeatedly thereafter. One attack on Dec. 1, 1938, was sufficiently severe to cause his admission to the hospital, where it was controlled with aminophylline, 5 grains in 200 c.c. of 25 per cent glucose solution intravenously.

Until early May, 1939, it appeared that little benefit had been derived from the operations, as the patient continued to have frequent and rather severe attacks of asthma necessitating injections of adrenalin and aminophylline for relief. Until that time the patient missed at least two days a week from school although he was able to "carry on" during the intervals. After May 3, 1939, the patient had a perfect attendance record at school and had only rare attacks of asthma, all of which were relieved completely within fifteen minutes by an injection of adrenalin.

A reply to a questionnaire dated Jan. 11, 1947, indicates that this patient is working in a factory in Detroit as a machinist. This past fall he had some asthma between September 6 and October 30, requiring "about two shots a day." In this period the patient states he lost some time from work because of his asthma, but the rest of the year he had been able to work continuously and regularly.

In 1943 our observation of the first three patients over a period of at least four years in each case was encouraging. Each patient had some evidence of bronchial damage and pulmonary emphysema so that none were entirely symptom free. However, each was able to work and a relatively small amount of medication was required to abort asthmatic attacks when the patients believed one to be impending. These observations encouraged us to advise and apply similar operations to two additional desperate patients with intractable asthmatic symptoms.

CASE 4.—R. T., aged 59 years, a white man, entered the hospital April 28, 1943, as an emergency because of extreme dyspnea, wheezing, cyanosis, and loss of consciousness.

The history obtained later indicated that the patient could not remember when he did not have attacks of asthma to a greater or lesser degree, but that in the preceding four months following a cold they had become much more severe and almost continuous. Cough with intermittent episodes of purulent sputum had been present for several years. There had been a loss of 25 pounds of weight in the preceding four months.

The patient's attacks of dyspnea had gradually become refractory to all types of medication including adrenalin, ephedrine, aminophylline and numerous patent remedies.

Physical examination showed an emaciated elderly man, unconscious, cyanotic, with all accessory muscles of respiration intensely active. There was ptosis of the right eyelid.

Examination of the chest showed a barrel-shaped thorax with limited excursion. There was a great deal of bronchial rattling to be heard on auscultation as well as both inspiratory and expiratory sibiles and musical râles. Heart sounds were distant and the heart rhythm was irregular.

Emergency treatment consisted of a bronchoscopic aspiration of secretions, nasal oxygen, 7½ grains of aminophylline in 10 per cent glucose, and rapid digitalization.

X-ray films and bronchograms obtained later showed a very marked bilateral pulmonary emphysema and extensive cylindrical bronchiectasis. All bronchi without bronchiectasis were attenuated.

The blood examinations showed a normal red cell count and hemoglobin with a white cell count of 15,600. Eosinophiles ranged from 4 to 8 per cent but the blood picture was otherwise not remarkable. The Kahn test was negative.

During the ensuing three months the patient was never completely free from his dyspnea and wheezing which varied from day to day in severity in spite of attempts to control it with all types of standard medical therapy. The bronchial infection was controlled adequately with a postural drainage routine supplemented with expectorants and a high fluid intake.

On Aug. 6, 1943, a left dorsal sympathetic ganglionectomy was performed by the technique previously described, except that in this case the second, third, fourth, and fifth thoracic sympathetic ganglia with the intervening sympathetic trunk were excised. During the operation a small tear was made in the pleura creating a pneumothorax, but with positive pressure the lung was re-expanded as the wound was closed in layers and no respiratory embarrassment was experienced.

By Aug. 30, 1943, the patient had gained 10 pounds in weight although he still experienced occasional slight attacks of asthma which were relieved with one Tedral tablet.

On Sept. 14, 1943, the contralateral right dorsal sympathetic ganglionectomy was performed, again removing the second, third, fourth, and fifth ganglia. Convalescence from this stage was uneventful. The patient was discharged from the hospital on the twelfth postoperative day.

On Oct. 14, 1946, the patient stated that he wheezed very little but that his chest ''stopped up'' occasionally, requiring a bronchoscopic aspiration of his secretions. He stated that these attacks of dyspnea are never severe enough to make him sit up to get his breath.

Physical examination revealed a normal temperature, pulse rate, respiration rate, and blood pressure of 140/80. His weight was 119½ pounds. Examination of the chest showed rhonchi predominantly in the right lung. Bronchoscopic examination showed a significant amount of mucopurulent secretion in the right lower lobe bronchi but the membrane in the other bronchi appeared relatively normal.

In response to a questionnaire dated January, 1947, the patient stated that he is actively managing his farm, that he sleeps fairly well, and that his appetite is good. He tends to have some ''choking spells'' in the late afternoon and at night but ''these attacks I have now are light and it just takes a few drops of adrenalin to stop them. I seem to be getting along fairly well.''

CASE 5.—T. B., aged 29, a white married man, an engineer. The patient was first seen on May 23, 1941, complaining of asthma and a cough productive of mucopurulent sputum.

The patient stated that fifteen years previously he began having attacks of asthma which became progressively worse until they would last for days at a time regardless of medication. There was a history of mucopurulent sputum following colds for many years.

Three weeks previously the patient had had ''flu'' with fever to 104°F. for three days, treated with sulfathiazole. He had experienced pleurisy in the left anterior chest following the acute infection.

Physical examination revealed an asthmatic white male in moderate respiratory distress. Blood pressure was 106/68 and weight 140 pounds, representing a recent loss of 6 pounds.

Chest examination revealed many inspiratory and expiratory siffles, râles and rhonchi bilaterally, particularly prominent in the right axilla.

X-ray film May 22, 1941, showed multiple cystic areas in the right midlung field with fibrotic infiltration extending out from the hilum into both lungs.

Bronchograms showed irregularity and slight cylindrical dilatation of the bronchi in both bases.

Bronchoscopy showed an edematous pale mucous membrane in the trachea and major bronchi with evidence of irregularity and scarring in the secondary branches.

The laboratory reported blood counts within normal limits and an eosinophilia ranging from 3 to 7 per cent. Sputum was negative for tubercle bacilli on both concentration and culture.

For two years the patient was treated with bronchial drainage routine including expectorants, tedral tablets, aminophylline, and occasional bronchoscopy. Attempts were made by competent allergists to eliminate contact with allergenic proteins to which the patient was sensitive and to desensitize him to those from which he could not be separated. For three months the patient was improved and gained 16 pounds in weight but in August, 1943, the attacks returned with renewed severity and the patient proved to be adrenalin-fast. At this time the patient was taking 12.0 c.c. of adrenalin a day without relief and he became anxious to submit to a sympathetic ganglionectomy.

On Aug. 27, 1943, a left sympathetic ganglionectomy was performed, removing the left second, third, fourth, and fifth dorsal sympathetic ganglia. Convalescence was uneventful and the patient left the hospital eight days later. For one week he had no asthmatic symptoms but at that time he caught a cold which renewed his cough, sputum, dyspnea, and wheezing.

On Oct. 8, 1943, the contralateral stage of the operation was performed, removing the right second, third, fourth, and fifth dorsal sympathetic ganglia. At this stage a tear was made in the pleura, but collapse of the lung was prevented by the application of positive pressure anesthesia and the wound was closed tightly without drainage. Convalescence was marred only by the discomfort of pleurisy, presumably due to a small amount of pneumothorax creating tension on some intrapleural adhesions. The patient left the hospital on the twelfth postoperative day with the lung well expanded.

Since operation the patient has had no severe attacks of asthmatic symptoms. It has been necessary for the patient to utilize the bronchial drainage routine from time to time to clear up the sequelae of respiratory infections.

In response to a questionnaire dated Jan. 8, 1947, the patient reported his general condition good. He stated that he has no severe attacks of asthma, but "chokes up some when I have a cold and usually tighten up a little on rising in the morning and about bedtime." He occasionally takes 0.2 c.c. of 1:1,000 adrenalin when his chest feels tight. He further declares that he had missed only a few days of work in the last two and one-half years.

Each of these last two patients has a known bronchiectasis, pulmonary emphysema, and one has actual cystic disease of the right lung. The present symptomatology is comparable to that experienced by all other patients with these irreversible changes in the bronchi and lung parenchyma.

RESULTS

From a statistical standpoint this small group of five patients is of no consequence. To the patients concerned the operations have been extremely important since all five have been enabled to return to useful occupations. From a surgical point of view the results are interesting because these patients have obtained as complete relief as those subjected to the more extensive operation effecting complete denervation of the lung.

All five patients upon whom we operated had intractable asthmatic symptoms of long duration. It is not surprising that there should be permanent changes in the bronchial mucous membrane such as thickening, loss of ciliary action, and, in two cases, bronchiectasis. Pulmonary emphysema is, of course, present in all cases. It is interesting that the residual symptoms of each of the five patients depend largely upon the presence or absence of respiratory infection at the time. It is believed that the symptoms of "choking up" and wheezing associated with colds are due more to these permanent bronchial and parenchymal changes than to the old asthma mechanism.

All five patients have gained weight in amounts varying from 10 to 100 pounds. Only two patients report losing any time from work because of "asthma" within the past year, neither of them for more than a few days. All patients report a satisfactory response to small amounts of medication when an impending attack is feared.

It is of further interest to note that the patients whose operations have been performed the longest (ten years) have progressively shown the greatest improvement.

SUMMARY

1. We are not prepared to say what the metabolic, biochemical, or systemic disorder underlying bronchial asthma may be, nor to propose a cure for the basic condition causing it.
2. Evidence is presented to indicate that a basic metabolic or systemic disorder producing the symptoms of asthma does exist.
3. Observations of reduction of bronchial lumina between attacks of asthma suggest that changes in the condition of the bronchial mucosa and its glands are responsible for intermittent attacks of symptoms, rather than contraction and relaxation of smooth muscle.
4. Opinions are quoted which contend that the vagus is not a simple bronchial constrictor nerve, but that the thoracic sympathetic trunks and ganglia also contain "constrictor fibers," and that their influence upon the bronchial mucosa and glands seems certain.
5. Sensitization to adrenin of structures which normally have a sympathetic nerve supply is suggested as a possible explanation for the effects of sympathetic denervation of the lungs in asthma.
6. An operation is described for the bilateral excision of the third and fourth dorsal sympathetic ganglia, and three cases of asthma so treated with beneficial results are reported. Two additional patients on whom bilateral excision of the second, third, fourth, and fifth dorsal sympathetic ganglia was performed are also described.
7. After observing the first patients for ten years and the later ones for four years, we are encouraged by the results obtained to proceed with the operation upon others whose asthma appears to be intractable.

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DISCUSSION

DR. OSLER ABBOTT, Atlanta, Ga.—At Emory University we have also been interested in this problem but have approached it by direct attack upon the parasympathetic nervous system. During the past two years we have utilized a transpleural approach in order to resect the pulmonary components of the vagus nerve in nine patients with intrinsic bronchial asthma. It appears particularly important to isolate the vagus throughout its entire course in the posterior hilar area. The number of branches going to the lung has been many more than one would expect, and we have noted a minimum of five branches on each side. There has been one to two branches along the superior surface of the pulmonary artery, a large branch along the posterior surface of the mainstem bronchus, and one along the posterior surface of both the superior and inferior pulmonary veins. On the left side there is frequently an additional branch going along the artery and arising from the inferior surface of the recurrent laryngeal nerve. We have also stressed the ligation of each branch prior to its transsection, and conclude the operation by transplanting the entire hilar portion of the vagus nerve into the pleural cavity, by interposing the mediastinal pleura between the nerve and the distal ends of the severed pulmonary branches.

The two sides in each patient have been operated upon at a minimum of a three-month interval, in order to allow us to observe the effect upon the individual lung. The patients have uniformly remarked upon a marked increase in respiratory reserve. We have noted a constant change in physical signs, in that there is a prolongation and accentuation of the expiratory phase of respiration, almost assuming a tubular quality.

The increase in the vital capacity has been our most striking finding. Inasmuch as all patients were only subjected to this experimental procedure when they had become totally incapacitated, and all had severe associated emphysema, we have rapidly come to the preliminary conclusion that our most beneficial effect has been upon the emphysema component of the disease. So strongly have we felt this, that recently we have utilized it in cases of emphysema alone. In the group with bronchial asthma the increase in vital capacity has ranged from 88 to 128 per cent.

However, we appreciate that we are dealing with a disease containing a major psychosomatic complex, and we do not feel justified in making any final interpretation until a five- to ten-year period of observation has elapsed.

DR. RALPH ADAMS, Boston, Mass.—I wish to ask two questions of Dr. Carr.

When he did the sympathectomy, did he go prior to or peripheral to the intercostal nerve root when he removed the dorsal sympathetic ganglion?

Second, did he observe some months later, when several of his patients began to have clinical improvement in their asthma any sign of Raynaud's disease or sweating in their hands?

The operation which he described corresponds closely to the operation which is now called by some people who do the preganglionic sympathectomy, the "old-fashioned sympathetic ganglionectomy," in that it was postganglionic instead of preganglionic in respect to the intercostal nerve root.

He gave the explanation of the sensitivity to adrenin. In part, the reason that the Raynaud disease patient got worse as he characteristically did from the old operation was shown dramatically by Norman Freeman and his colleagues to be caused by sensitization to his own adrenin, perhaps from nerve regeneration.

Possibly what was a ganglionic sympathectomy may explain the delayed appearance of beneficial results in some of Dr. Carr's cases.

We have operated upon four patients with severe pulmonary emphysema and cysts, in each of whom there was at least one cyst causing mechanical embarrassment to the patient's respiration. In each of those four cases, the cyst of greatest size was removed. The hundreds of others naturally were not attacked; the cyst wall was enfolded, and at the same time two autonomic nerve types of operation were done, one Dr. Abbott has just mentioned, removing the vagal fibers in the hope of attacking the bronchial spasm phenomena, and second, the sympathetic fibers, in the hope of recreating a sensitization to their own adrenin, if it be of practical value, as we thought it might be from theoretical considerations.

One of those patients died. The other three had greater improvement than I had any idea they would or should have had. Each of these three patients changed from invalidism to a useful but light occupation, one patient four years after operation, is just now, in the past three months, beginning to return to a status comparable to that at the time he was operated on.

Another patient was suspected of having carcinoma, but had a granuloma in his right lung. Because he had asthma, a unilateral vagal denervation was done, and I could not see that it did him any good.

One patient had a bilateral operation of the specific type that Dr. Carr described, for severe asthma, of the type that required oxygen therapy and air-conditioned rooms. Her reaction after the first side was dramatic. There was great improvement. She was anxious to have the second side done, and she improved further and went home, she claimed, a well patient. She stayed well for five weeks, and in the sixth week had a family argument and returned to the hospital in status asthmaticus. Five months later that patient had again begun to show improvement. We had our psychiatrist look into the matter, which may be the explanation.

DR. J. HUGHES CHANDLER, Jackson, Tenn.—The type of resection done was postganglionic, and in none of these resections was there noted any evidence of Raynaud's disease postoperatively.

We were especially interested in a comparison of results between the dorsal sympathectomy as it was done to include stellate ganglia and those of the type which we have done. We have purposely excluded stellate ganglia because of the unpleasant symptoms that would have been produced by Horner's syndrome.

I would like to further emphasize that denervation operations will afford no benefit to patients whose bronchial tree has become rigidly constricted by chronic fibrosis, or in advanced emphysema.

DR. DUANE CARR, Memphis, Tenn.—Frankly, we now feel we know nothing for sure about asthma. Ten years ago when this work was started we felt confident in our knowledge, but conflicting opinions in the literature and observed physiological results which cannot be reconciled with them leave us feeling ignorant. We hope that this will result in our learning something more definite.

It is high time we held up some of the old ideas which have been taken for granted to close scrutiny. I feel right now that, as Dr. Grace has said, the entire physiology of asthma needs to be reviewed.

As for the relative merits of the dorsal sympathectomy, dorsal sympathetic ganglionectomy, and the posterior pulmonary plexus neurectomy, we have no opinion. We were trying to get away from an extensive transpleural operation. Our patients were so desperately ill that they could hardly have tolerated a major procedure of that type.

If the simple resection of the dorsal sympathetic ganglia will serve the purpose, and after watching some of these patients for ten years, we believe it has; we believe that the amount of surgery or surgical trauma necessary to bring relief has been greatly minimized.

ARTERIOVENOUS FISTULA OF THE LUNG

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THE development of large, vascular channels between a pulmonary artery and vein results in a characteristic clinical syndrome which is being recognized with increasing frequency.[1, 4, 5, 7, 10-16] We are herewith reporting a study of the circulatory dynamics in pulmonary arteriovenous fistula. The disturbances in circulation associated with an arteriovenous fistula in a large peripheral vessel have been the subject of intensive investigation.[9] The data reveal points of contrast between the alteration in circulatory dynamics produced by arteriovenous fistula in the lesser as compared with the greater circulation. Included in this paper is a case report of a pulmonary arteriovenous fistula with superimposed bacterial endarteritis, which was successfully treated by chemotherapy and lobectomy. To our knowledge this is the first case of bacterial endarteritis superimposed on a pulmonary arteriovenous fistula that has been observed.

An arteriovenous fistula not caused by trauma, infection, or degenerative changes in the walls of blood vessels is a form of cavernous hemangioma. The size of the vascular channels in hemangiomas varies considerably. When large arteries and veins are present, a free communication between the arterial and venous system may be established. A cavernous hemangioma of the lung may result in the shunting of a considerable amount of venous blood from the pulmonary artery to the pulmonary vein and left auricle. The blood passing through the shunt does not go through the capillaries of the lung and thus fails to be oxygenated in the normal manner. Since the lung has a dual blood supply from the pulmonary and bronchial systems, one or more tributaries of both systems may communicate with the cavernous hemangioma. The part played by each vascular system varies in different cases. Those patients who show marked cyanosis, clubbing of the fingers, and polycythemia undoubtedly have a large fistulous communication between the pulmonary artery and vein. In the absence of cyanosis and polycythemia, cavernous hemangioma of the lung may be suggested on physical examination by the presence of a loud murmur over a portion of the lung. Perhaps in the latter instance the bronchial arteries play a more prominent role in supplying blood to the cavernous hemangioma. If this hypothesis is correct, the pressure within such a cavernous hemangioma might be greater and the risk of hemoptyses increased.

Heredity seems to play a role in the occurrence of arteriovenous fistula of the lung. Goldman[5] has reported hemangioma in the lungs of two brothers.

Read at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29 and 30, 1947.

From the Departments of Surgery and Medicine, Columbia University, and the Cardiopulmonary Laboratory of the Chest Service (Columbia University Division), Bellevue Hospital.

Investigation aided by a grant from The Commonwealth Fund.

Whitaker[16] reported a case of pulmonary arteriovenous fistula with a family history of telangiectases. One of our patients gave a history of multiple telangiectases in three generations.

The symptoms in arteriovenous fistula of the lung tend to vary, depending partly on the degree of polycythemia. The patient may be asymptomatic, but in most of the cases reported symptoms have been noted. Cough is only an occasional complaint. Dyspnea on exertion is often present, particularly if the arteriovenous shunt is large. Hemoptysis may occur and sometimes the bleeding is severe and may even be fatal.[2] There are usually no symptoms of pulmonary infection, but one of our patients developed septicemia due to bacterial endarteritis occurring in the arteriovenous fistula. Headache occurs in patients with marked polycythemia and one patient had epileptiform seizures.[14] Epistaxis is not infrequent.

The physical findings in arteriovenous fistula of the lung may vary. Approximately one-half of the patients have hemangiomas elsewhere, particularly around the head. Telangiectasia of the lips is common. Polycythemia and clubbing of the fingers and toes are present in those patients with cyanosis. There is often a history of cyanosis dating from early life, and in some cases this was noted shortly after birth. The cyanosis tends to become worse as the patient grows older. The cardiac findings are normal. The heart is not enlarged. In about half of the cases a murmur may be heard over the portion of the lung field where the arteriovenous fistula is located. The murmur tends to be louder during inspiration, and may be almost continuous in character, often with systolic accentuation. The roentgen findings are rather characteristic. One or more areas of density in the lung field may be noted. The shadow may be somewhat rounded, but often has an irregular border and sometimes the margin is wormlike. Pulsation may be noted on fluoroscopy. The density is usually continuous with the vascular markings, and the vessels leading to it are usually enlarged. Stereoscopic views and planograms may demonstrate the connection with the pulmonary vascular tree to better advantage. Angiocardiograms confirm the diagnosis (Fig. 1). It would seem advisable to perform angiocardiography in every case of arteriovenous fistula of the lung prior to operation, since by this method multiple arteriovenous fistulae which are not obvious on a routine roentgenogram may be demonstrated. In approximately one-half of the reported cases, multiple lesions in the lung have been found. Lesions occurring at the pulmonary bases may be obscured by the cupula of the diaphragm and those in the medial portion of the left base may be obscured by the cardiac shadow.

The laboratory findings in cavernous hemangioma of the lung are dependent upon the size of the shunt from pulmonary artery to pulmonary vein. The red blood cell count may be as high as eleven million, and a hemoglobin as high as 23.7 Gm. has been reported.[15] In one case the hematocrit was 80 per cent. The blood count may be normal if there is no significant shunt between the pulmonary artery and vein. An arterial oxygen saturation at rest as low as 70 per cent has been recorded. In one of our patients the resting arterial oxygen saturation was 74 per cent, but on exercise it dropped to 59 per cent.

Cavernous hemangioma of the lung with polycythemia must be differentiated from other lesions which produce an abnormally high erythrocyte count. In the past, diagnoses of polycythemia vera have been erroneously made. The absence of splenic enlargement should aid in differentiation. Hirsch[8] has reported pulmonary lesions in polycythemia vera which were probably caused by intravascular thrombosis. These lesions can be differentiated from pulmonary arteriovenous fistulae by their changing character on serial films and their tendency to clear. The absence of any clinical or roentgen evidence of cardiac abnormalities should differentiate pulmonary cavernous hemangiomas from congenital cardiac lesions. Polycythemia due to diffuse pulmonary disease and chemicals must be ruled out.

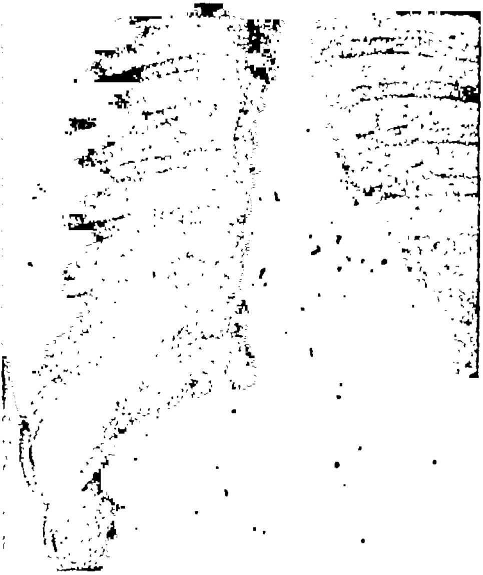


Fig. 1.—Angiocardiogram shows large arteriovenous aneurysm in right lung outlined by diodrast. Note the large pulmonary vein leading from the vascular mass. (Courtesy of Dr. M. Sussman.)

Cases of cavernous hemangioma without polycythemia and cyanosis may be suspected on the basis of a murmur heard over the involved portion of the lung. If no murmur is audible, it may not be possible to establish the diagnosis by the roentgen appearance alone unless the contour of the shadow strongly suggests a vessel. In such cases, angiocardiography will be conclusive. Murmurs may also be produced by arteriovenous fistulae in the chest wall.

Malignant hemangiomas may occur in the lung as elsewhere.[3, 6, 17] They are very rare and do not produce the signs of pulmonary arteriovenous fistulae. The tumor, however, may be very vascular. Usually the metastases are widespread.

The chief and most common complications of arteriovenous fistula of the lung are those associated with polycythemia. Hemoptysis has occurred in the minority of cases, but is a potential hazard because of the severity of the bleeding which may occur. The possibility of bacterial endarteritis exists in any case of arteriovenous fistula, irrespective of its location.

The treatment of pulmonary arteriovenous fistula is surgical excision. Since the lesions may be multiple, and because of the possibility of additional arteriovenous fistulae becoming manifest later, conservation of pulmonary tissue is indicated. Local or segmental resection of the lung is feasible in some cases. Usually either lobectomy or pneumonectomy has been required, depending upon the size and location of the vascular channels. Because of the possibility of associated vascular anomalies, one should be certain that adequate channels for the return of blood to the left heart remain. In the case reported by Jones and Thompson,[12] a single pulmonary vein was present. Had this not been recognized and only a lobectomy performed, the returning blood flow from the remaining portion of the lung would have been obstructed.

In two cases of arteriovenous fistula of the lung reported in the literature, an attempt was made to lessen the blood flow through the shunt by the induction of a pneumothorax.[7, 12] A good collapse of the lung was obtained in both instances, but after several months of pneumothorax there was no appreciable change in the degree of polycythemia. The results indicate that collapse of the lung causes little change in the amount of blood passing through the arteriovenous fistula.

CASE REPORT

M. F., a 20-year-old woman, stated that her fingernails and lips had been blue as long as she could remember. Her mother was uncertain as to whether she had been "blue" at birth, but had noticed increasing cyanosis since infancy. Clubbing of the fingers had been present for many years. She tired easily on exertion and showed some dyspnea. These symptoms had become more marked in the past few years. In 1941 a chest roentgenogram had revealed an area of density in the right lower lobe (Fig. 2), but the nature of the lesion was not recognized. Epistaxis had occurred frequently since 1944. In February, 1944, an abscess appeared in the right ankle region. This healed slowly after drainage. In the early part of 1946 an abscess developed over the heel on the same side. It was incised and pus containing nonhemolytic streptococci was obtained. Drainage had continued for four weeks when the patient suddenly became acutely ill with a high fever. On admission to the hospital, in March, 1946, a roentgenogram of the chest showed a defect in the sixth rib on the left side and a diagnosis of osteomyelitis of the rib was made. The chest roentgenogram (Fig. 3) also showed a dense area at the right base which was considerably larger than that seen on the x-ray film taken five years previously. While in the hospital the patient ran a febrile course and a blood culture taken on admission was positive for nonhemolytic streptococci. A left-sided empyema due to the same organism developed, and was treated by intrapleural instillations of penicillin combined with large doses by intramuscular injection. Sulfadiazine was given by mouth.

Physical examination revealed cyanosis of the mucous membranes, fingers, and toes. Clubbing of the fingers and toes was marked. Acne vulgaris of the face, chest, and back was present. There was marked myopia and internal strabismus. The thyroid was slightly enlarged. Heart sounds were normal; no murmurs were present. The blood pressure was 100/70 mm. Hg. An electrocardiogram was normal. At the base of the right lung posteriorly a continuous murmur could be heard over an area several centimeters in diameter. The murmur was louder during inspiration and there was slight systolic accentuation. The area of

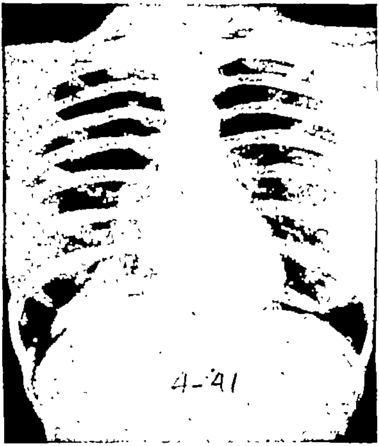
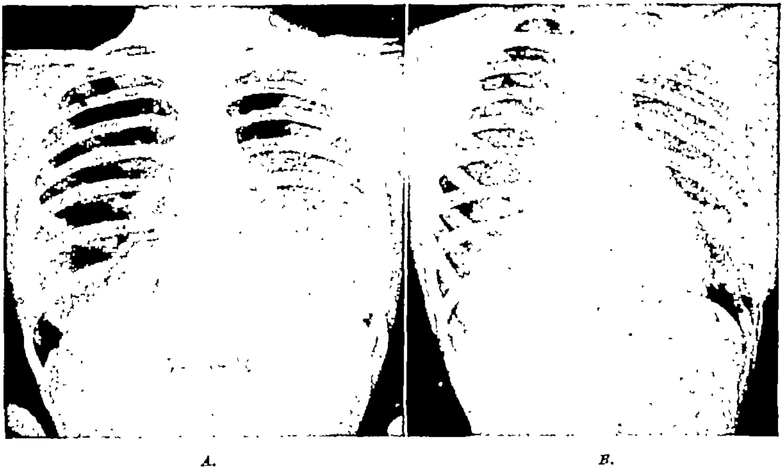


Fig. 2.

Fig. 3.

Fig. 2.—Roentgenogram in 1941 showed an area of density in the right lower lobe.

Fig. 3.—Roentgenogram in 1946 showed density over the left hemithorax due to empyema. A defect in the left sixth rib, due to osteomyelitis, is present. The area of density at the right base, which is the arteriovenous fistula, has enlarged considerably in the five-year interval.



A. *B.*

Fig. 4.—*A*, Roentgenogram of chest taken before operation for arteriovenous fistula. The left sided empyema has cleared. *B*, Oblique view shows aneurysmal sac above diaphragm.

the murmur corresponded with the location of the density seen in the right lung field on the roentgenogram. A diagnosis of bacterial endarteritis occurring in an arteriovenous fistula of the right lower lobe of the lung was made. Because of the presence of the left-sided empyema, no surgical intervention for the arteriovenous fistula in the right lung was feasible at this time. Over 12 million units of penicillin were given during a four-week period. Sulfadiazine was continued for many weeks and the temperature gradually approached normal. The osteomyelitis of the rib and the empyema subsided. The blood cultures remained negative after the first few weeks of illness. Excision of the arteriovenous fistula of the right lung was delayed until the pleuritic reaction on the left side had thoroughly subsided (Fig. 4). During the interim a maintenance dose of one gram of sulfadiazine daily was given. Several months after the septicemia had cleared, the bruit at the base of the right lung was heard only with difficulty. Angiocardiogram confirmed the diagnosis of pulmonary arteriovenous fistula (Fig. 1). At operation on Nov. 20, 1946, a right lower lobe lobectomy with excision of the arteriovenous fistula was performed. Because of the patient's marked polycythemia, infusion was given prior to operation to lessen the hazard of intravascular thrombosis. Only blood plasma was given during the operative procedure. The pulmonary artery to the lower lobe was found to be tremendously enlarged and very thin, while the vein from the lower lobe appeared normal. This thinning out of the wall of the artery, which is also present in peripheral arteriovenous fistulae, has been called venafication of the artery. The aneurysmal sac was densely adherent to the diaphragm, due to a chronic inflammatory reaction. The color of the patient improved as soon as the artery was ligated.

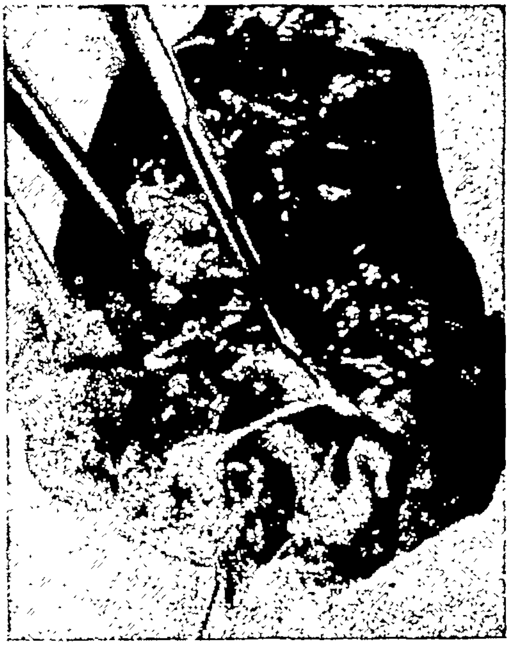


Fig. 5.—Photograph of specimen showing aneurysmal sac of arteriovenous fistula of the lung.

The excised lobe of the lung revealed a large, thin-walled pulmonary artery which entered a large sac with some recesses. Another opening in the thin-walled sac led to the pulmonary vein. On a ridge on the inner aspect there was a thickened area which probably represented the site of previous vegetations. It required 150 c.c. of solution to distend the vascular channels of the cavernous hemangioma. The sac alone had an 80 c.c. volume (Fig. 5).

The postoperative course was essentially uneventful. The right upper and middle lobe expanded well (Fig. 6). The postoperative drop in red blood cell count and hematocrit was more pronounced than could be accounted for by the estimated blood loss at the time of operation.

Studies of the respiratory and circulatory function were done before operation and on four occasions during the ensuing six months (Charts I, II, III). Before operation the lung volumes were normal (Chart I), but the oxyhemoglobin saturation of the arterial blood was 74 per cent at rest and dropped to 59 per cent after the standard exercise test (Chart II). The oxygen content of the arterial blood was 20.6 volumes per cent and of the mixed venous 16.4 volumes per cent. Cardiac catheterization studies revealed a normal *cardiac output and normal pressure relationships in the right auricle, right ventricle, and* pulmonary artery (Chart III and Fig. 7). The shunt through the arteriovenous aneurysm was estimated to be 58 per cent of the total blood flow at rest. Plasma volume was normal and total blood volume was increased due solely to the large volume of red cells; the hematocrit was 70 per cent.

CHART I. OBSERVATIONS ON THE LUNG VOLUMES, THE MAXIMUM BREATHING CAPACITY, AND THE SEPARATE FUNCTIONS OF THE RIGHT LUNG IN A CASE OF PULMONARY ARTERIOVENOUS FISTULA

M.F. 20 YEARS	PREDICTED	BEFORE OPERATION	FIVE MONTHS AFTER OPERATION
Vital capacity (liters)	3.0	3.3	2.3
$\frac{\text{Residual air}}{\text{Total lung volume}} \times 100$	26	26	34
Maximum breathing capacity (liters per minute)	96	74	81
Bronchospirometry (percentage of total function on the right side)			
Vital capacity	53	57	38
Ventilation	53	49	49
Oxygen intake	53	42	25

CHART II. OBSERVATIONS ON THE BLOOD VOLUMES AND OXYGEN TRANSPORT IN A CASE OF PULMONARY ARTERIOVENOUS FISTULA

M.F. 20 YEARS	NORMAL	BEFORE OPERATION	SIX MONTHS AFTER OPERATION
Blood volumes (c.c./Sq.M.B.S.A.)*			
Total volume	2,700	4,800	2,170
Plasma volume	1,600	1,460	1,350
Red cell volume	1,100	3,340	820
Hematocrit (%)	40	70	36
Red cell count (million)	5.0	6.9	4.4
Hemoglobin (Gm.)	14.5	22	13
Oxyhemoglobin saturation (%)			
At rest	96	74	96
After exercise	96	59	90

*c.c./Sq.M.B.S.A. = Cubic centimeters per square meter of body surface area.

CHART III. BLOOD PRESSURES IN THE RIGHT HEART AND PULMONARY ARTERY, AND CARDIAC OUTPUT* IN A CASE OF PULMONARY ARTERIOVENOUS FISTULA

M.F. 20 YEARS	PRESSURES (MM.HG)		
	SYSTOLIC	DIASTOLIC	MEAN
Brachial artery	97	59	78
Pulmonary artery	17	8	12
Right ventricle	17	4	—
Right auricle	—	—	3

*Systemic blood flow (Cardiac Output) = 3.24 L./Sq.M.B.S.A./min. Arteriovenous shunt = 58 per cent of total pulmonary blood flow.

After lobectomy the blood volume and hematocrit returned to normal within four days. The oxyhemoglobin saturation of the arterial blood likewise returned to normal at rest but showed a small drop to 90 per cent after the standard exercise. The tendency for the arterial oxyhemoglobin saturation to be slightly low during exercise has persisted but has not increased, and it has been shown not to be due to a low partial pressure of oxygen in the alveolar air. The evidence suggests that during exercise a small proportion of venous blood fails to become oxygenated in the lungs. Whatever the nature of this shuntlike mechanism, it is so small as to be of no functional importance.

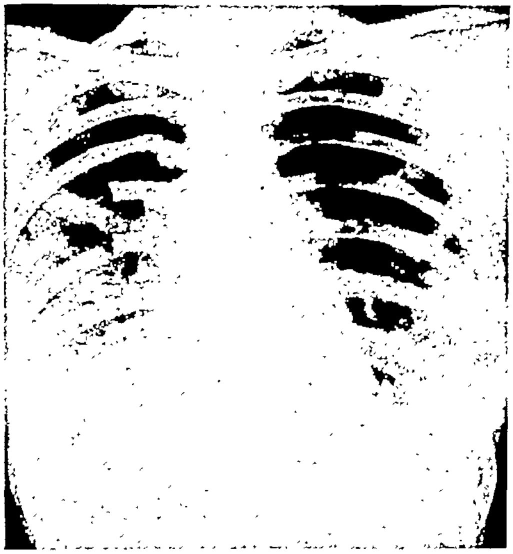


Fig. 6.—Postoperative roentgenogram shows good expansion of the right upper and middle lobes following lower lobe lobectomy.

An interesting finding during the postoperative period was a high partial pressure of carbon dioxide in the arterial blood. This was still present after two weeks but had returned to normal four months later. Preoperatively the partial pressure of carbon dioxide in the arterial blood was somewhat elevated because of the admixture of venous blood by way of the pulmonary shunt. After operation the maintenance of a high arterial carbon-dioxide pressure can have resulted only from a high alveolar carbon dioxide, due in turn to hypoventilation. This finding is probably a manifestation of the effect upon the respiratory center of the change in acid-base relationships occurring after closure of the pulmonary arteriovenous shunt. No such change occurs in a peripheral arteriovenous shunt.

A comparison of the physiological effects of peripheral and pulmonary arteriovenous fistula is of interest (see Chart IV). According to Holman,[9] an arteriovenous fistula between an artery and vein in the greater circulation results in an increase in the blood volume. The plasma and red cell volume are both increased proportionately so that the hematocrit remains essentially normal. In pulmonary arteriovenous fistula, however, the increase in blood volume is due solely to the increase in red cell mass while the plasma volume remains normal. The cardiac output is markedly increased in the presence of a large peripheral arteriovenous fistula, whereas we found a normal value in the one case of large pulmonary arteriovenous fistula in which the cardiac output was determined. Cardiac enlargement, mainly due to dilatation, is an important finding in large peripheral arteriovenous fistula. No enlargement of the heart has been observed in the reported cases of pulmonary cavernous hemangioma, and this may be related to the normal pressures in the right ventricle and pulmonary artery and normal cardiac output found in the case studied by cardiac catheterization. Following elimination of a long-standing peripheral arteriovenous fistula with a proved increase in blood volume, there occurs a temporary concentration of hemoglobin and an increase in red cells per cubic millimeter of blood. A drop in the hematocrit and erythrocyte count occurs after elimination of a pulmonary shunt.

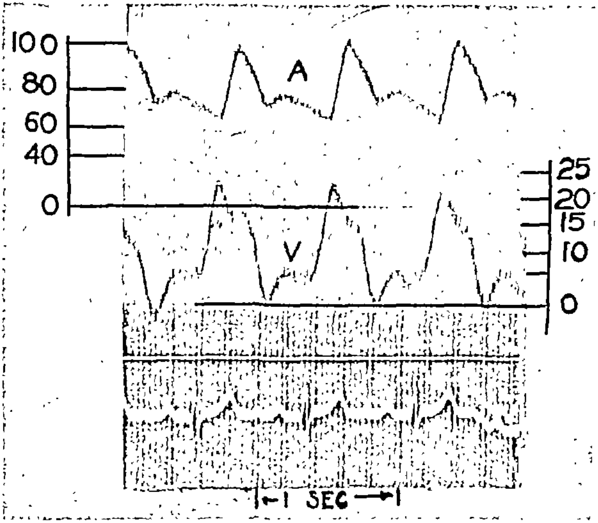


Fig. 7.—Tracings of the pressure in the brachial artery and right ventricle. All pressures in mm. Hg.

A = Pressure as recorded from brachial artery (scale to left).
V = Pressure as recorded from right ventricle (scale to right).
ECG = Normal Lead II.

CHART IV. PHYSIOLOGICAL EFFECTS ON THE CIRCULATION; CONTRAST BETWEEN LARGE SYSTEMIC AND LARGE PULMONARY ARTERIOVENOUS FISTULA

	ARTERIOVENOUS FISTULA	
	SYSTEMIC	PULMONARY
Total blood volume	Increased	Increased
Total plasma volume	Increased	Normal
Hematocrit	Normal	Increased
Oxyhemoglobin saturation	Normal	Decreased
Cardiac output	Increased	Normal*
Cardiac enlargement	Present	Absent

*One determination.

SUMMARY

Cavernous hemangioma of the lung may result in a pulmonary arteriovenous fistula with the development of cyanosis, polycythemia, and clubbing of the extremities, but these signs are absent in those pulmonary hemangiomas which do not result in a significant degree of shunt between the pulmonary artery and vein.

A case of arteriovenous fistula of the lung with superimposed bacterial endarteritis successfully treated with parenteral penicillin followed by surgical removal of the involved portion of lung is reported.

A summary of the preoperative and postoperative study of the cardiocirculatory and pulmonary function, including information obtained by cardiac catheterization, is presented.

The physiological alterations produced by an arteriovenous fistula in the peripheral and pulmonary circulation are compared. A peripheral arteriovenous fistula increases all elements of the blood volume proportionately, increases cardiac output, and causes dilatation of the heart. In contrast, a pulmonary arteriovenous fistula increases only the red cell mass, and has little or no effect on cardiac output and cardiac dynamics.

The authors wish to acknowledge their indebtedness to Dr. André Cournand for his guidance and advice.

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DISCUSSION

DR. RICHARD H. SWEET, Boston, Mass.—We are indebted to Dr. Maier for his singularly lucid presentation of this interesting subject, and particularly for his very adequate physiologic studies which explain the mechanism of some of the interesting findings.

Its relative rarity in our cumulative experiences is such that some slides of two such patients out of three whom I have seen in the last two years might be of interest.

(Slide.) This is a young woman of 23 years, who suffered very few physical limitations. Her only complaint was that she disliked being about, among people. Her reasons for having something done were largely social.

(Slide.) This slide is not entirely satisfactory, but it does show that the middle lobe, held by the assistant's hands, looks as thought it has a hemangiomanous lesion in it. There is one tie on an enormous pulmonary artery and another on a very large pulmonary vein.

(Slide.) This shows a specimen which indicates that there was this large vascular lake in the middle lobe, which was the location of the lesion.

(Slide.) This slide shows the young woman several months later, and it is obvious that cyanosis and clubbing have almost disappeared.

(Slide.) This is a little child who was cyanosed from birth. In fact, we have x-rays of this patient at the age of one week which show the same findings we see in the next slide.

(Slide.) This large area in the right lung field shows also that this lesion is in the middle lobe. This seems to be the characteristic location.

(Slide.) The specimen was purposely filled with blood by tying the veins before the artery, and you see these large vascular areas.

(Slide.) This slide shows the child a few weeks following the operation, and he, likewise, apparently has very few symptoms. Even before operation he was a pretty normal youngster.

I have seen a third patient—upon whom I intend to operate—who also has a lesion in the middle lung field. The third patient, however, does not have cyanosis, and I would like very much to have Dr. Maier comment on the type of case where there is no cyanosis present.

DR. PAUL C. SAMSON, Oakland, Calif.—I wish to present briefly the history of a 25-year-old man who recently underwent exploration for an unidentified infiltrative lesion of the right middle lobe. At operation, an arteriovenous fistula occupying most of the middle lobe was diagnosed. The anomalous artery was a branch of the upper lobar artery and entered the middle lobe through an incomplete fissure between the upper and middle lobes. Lobectomy was performed without incident.

A pulmonary shadow was found by a routine roentgen survey and the fistula was not suspected prior to operation. There were no localizing physical signs in the lung, and the patient did not have clubbing of the fingers. His hemoglobin was 18 Gm. (115 per cent) and the red blood count was 5,810,000. Of particular interest was the patient's "asthmatic" history which was, in large measure, responsible for our not suspecting an arteriovenous fistula. The patient was supposed to have had seasonal asthma for the past nine years and there was an indirect report that fluoroscopy of the chest some four years ago had been negative. This report has not been confirmed. The patient had an allergic attack considerably more marked than usual in February, six weeks before operation. He was admitted to the hospital in a semiconscious condition with severe cyanosis and marked expiratory dyspnea. At that time there were numerous musical râles and rhonchi throughout both lungs. This attack apparently responded to adrenalin, aminophyllin, and bronchoscopy. It will be very interesting to follow this patient and determine whether the "asthma" may not be improved or even cured by the removal of the arteriovenous fistula.

DR. LAWRENCE M. SHEFTS, San Antonio, Texas.—There are two points of interest in relation to this type of case that will bear discussion. One is the familial tendency and the other is the readiness with which phlebothrombosis occurs in these patients because of extremely high specific gravity of the blood.

With these points in mind, I would like to present a case of a patient seen at Brooke General Hospital, San Antonio. The patient to be presented is one of a family of seven, all of whom, mother, father, daughter and four sons, presented evidence of telangiectasia and hemangioma of the skin and mucous membrane. Two of the family presented evidence of arteriovenous fistula of the lung.

The father of this patient had such hemangiomas of the lips that he could not go out in the sunlight or he would bleed from them. This is a very common story, as such patients are very sensitive to the sun. He finally had to take a job as a night watchman. He eventually died from a pulmonary embolism from phlebothrombosis of the lower extremities. He was known to be moderately cyanotic and probably had a marked polycythemia with a high specific gravity of the blood.

(Slides.) These are kodachrome lantern slides of the mother and sister. Telangiectasia can be seen on the chests.

(Slide.) The next is a kodachrome lantern slide of a brother and, though they do not show up too well here, he has small hemangiomas on his face and on his lips.

(Slide.) This is another brother; the hemangiomas on his lips can be seen more readily.

(Slide.) On kodachrome lantern slide of the third brother the hemangiomas are readily visible. The next lantern slide will show an x-ray on this particular brother.

(Slide.) In the left lower lung field is an area of opacity which I am sure is an arteriovenous fistula.

(Slide.) This is a lateral x-ray which shows this area of opacity in the lingula. Angiocardiography revealed that this was definitely an arteriovenous fistula.

(Slide.) This is a kodachrome lantern slide of the patient. It is readily visible that he had a marked cyanosis with similar areas of telangiectasia and numerous hemangiomas as were seen in the slides of his brothers. He had a polycythemia of 8,992,000; hemoglobin of 125 per cent; blood specific gravity of 1.068. He had had a previous history of thrombosis of the veins of his leg. Plasma specific gravity was 1.028; plasma protein 7.82; hematocrit 58 per cent; blood oxygen saturation: blood hemoglobin, 22.7 Gm. per 100 c.c.; femoral artery, 19.05 volumes per cent of oxygen; venous blood, 11.09 volumes per cent oxygen. Therefore, the per cent of saturation of arterial blood was 63 per cent and venous blood was 40 per cent saturation.

(Slide.) This x-ray reveals the mass to be in the right hilar region and the next slide, revealing a lateral view, shows it to be in the posterolateral portion of the right lower lobe.

(Slide.) This is an x-ray of an angiocardiography that was done, and, although it is not as clearly defined as the excellent one Dr. Maier showed, you can see that it is the same density as the heart.

(Slide.) This kodachrome lantern slide is taken during the operation after mobilization of the right lower lobe. It shows a large fist-sized mass in the posterolateral portion of the right lower lobe.

(Slide.) Another kodachrome lantern slide taken during operation after a similar mass was freed from the subclavian vessels shows another arteriovenous fistula in the apex of the right upper lobe. Scattered throughout the right middle and the lower portion of the right upper lobes were numerous ½ to 1 cm. large, bluish-black hemangiomas, and, although these did not pulsate as the larger one in the lower lobe and the one in the apex, it was felt that these, too, were arteriovenous fistulas. There were seven of these altogether and it was then decided that a total pneumonectomy rather than a lobectomy with numerous segmental resections would be done.

(Slide.) This is a kodachrome lantern slide taken of the patient's face the moment after the pulmonary artery was tied. The immediate change in color is obvious.

(Slide.) This is a picture of the patient one week postoperatively with no cyanosis.

(Slide.) The clubbing of his fingers has remained.

He developed postoperatively a thrombophlebitis in spite of the fact that he received no whole blood during operation. Only plasma was given in an attempt to reduce the specific gravity of his blood. I did not feel it safe to rely only on anticoagulants with a patient who had only one lung and, therefore, very promptly tied off both of his superficial femoral veins.

This case, I believe, demonstrates clearly the remarkable familial tendency of this disease and also the complications of handling such a patient with a high specific gravity of blood.

DR. FRANCIS R. X. BYRON, Ann Arbor, Mich.—I would like to present a case that has been encountered within the last fifteen months, because it illustrates something which has not been brought out in previous discussion.

(Slide.) This patient was 27 years of age, and had been cyanotic since birth. Her red count was 8½ million.

(Slide.) This shows the lateral chest x-ray, demonstrating the pulmonary opacity. It was thought to be in the middle lobe, but at operation it was found to be in the anterior surface of the lower lobe.

(Slide.) The probe to your left is through the pulmonary artery, the lower end of that probe, emerging through the inferior pulmonary vein, demonstrates a direct shunt from the artery to the vein. There was no murmur, and no thrill on palpitation.

The thing this patient illustrates is that the cyanosis may not immediately disappear. We were very disappointed because she continued to be somewhat cyanotic, and to have an elevated red count. We felt that perhaps we had missed another arteriovenous shunt elsewhere, but we have followed her for about fourteen months and we have found that each time she appears at the hospital, there is a decrease in her red count. One should not be disappointed if there is not an immediate fall in the red count or rapid disappearance of cyanosis.

DR. DEWEY BISGARD, Omaha, Neb.—It is becoming increasingly apparent that this lesion is not as rare as we once thought. It was first reported in 1942, and well over twenty cases have accumulated in the last five years. It was probably misdiagnosed and not recognized in the past.

I have one case to go over briefly. This man was 20 years old. He had increasing cyanosis following an upper respiratory infection eight years previously, and for three years he had dyspnea, asthmatic sort of attacks, and brief periods of loss of consciousness. For three months he had not been able to work because of the dyspnea.

(Slide.) On physical examination, he had hemangiomas of the lips, and moderate cyanosis with slight clubbing of the fingers and toes. A continuous murmur could be heard over the right lower lobe where you see this lesion in the lung field, and this murmur was accentuated on inspiration and diminished on expiration. It was heard over the eighth rib, posteriorly. I think you can see two branches leading off medially from this lesion. This is characteristic.

(Slide.) I did a right lower lobectomy and this is the film of the injected specimen. One pipette is in the artery and one in the vein. The artery was injected with barium and the film shows the filled hemangioma.

(Slide.) This is the man before operation, and I think you can see the hemangiomas of the lip, some clubbing, and moderate cyanosis.

(Slide.) Following operation, there was prompt clearing of the cyanosis. A moderate preoperative polycythemia and polyemia, also receded rather quickly.

(Slide.) This is the same patient, two weeks postoperatively.

DR. OSLER ABBOTT, Atlanta, Ga.—I wish to present, very briefly, a different type of an arteriovenous communication in the lung, in which we apparently carried out an incorrect plan of attack.

This was in the case of a child 14 years of age, who was admitted with a fairly typical syndrome of tetralogy of Fallot. He had the additional finding of a venous hum over the upper left chest. Preoperatively, the question of pulmonary arteriovenous fistula or inadequate persistent ductus arteriosus was considered.

At the first operation, done through the left side because of a right-sided aortic arch, we encountered an abnormal, large vein travelling from the superior vena cava to the first division of the left pulmonary artery, and at this point an aneurysmal area was found.

Considerable time was lost in study, dissection, and evaluation of the hydrostatic pressure on each side of the fistula. The pressure differences were not striking, but we removed the abnormal vessel and the aneurysmal communication, and repaired the left pulmonary artery. This appeared to be sufficient surgery at this time so that the second stage was carried out two months later. It was interesting to note that during the interval his cardiovascular function was definitely not improved, and the hematocrit had risen seven points. We now are of the opinion that the blood had originally been flowing from the vena cava into the pulmonary arterial system, and was probably proving to be of partial benefit to the patient. I feel, therefore, that if this anomaly is again encountered that it is much more important to treat the underlying tetralogy than the associated arteriovenous fistula.

DR. HERBERT C. MAIER, New York, N. Y.—I assume that in those cases of arteriovenous fistula with absence of cyanosis, the shunt is largely concerned with the bronchial vascular system. Such patients may have a louder murmur than some with a large shunt between the pulmonary artery and vein. However, actual proof of that hypothesis is not available at this time, and I feel that it would be desirable if these lungs would be thoroughly studied from the standpoint of the bronchial arterial system as well as the pulmonary system by injecting the vascular tree of the surgical specimen.

In the case which I presented there was considerable blood loss at operation, due to the inflammatory reaction where the aneurysmal sac was adherent to the diaphragm. But even allowing for that blood loss, we feel that the drop in the hematocrit from 70 to 34 in a few days cannot easily be explained on that basis alone.

SURGICAL TREATMENT OF THE SOLITARY LUNG METASTASIS

Donald B. Effler, M.D., and Brian Blades, M.D.
Washington, D. C.

THE ideal treatment of malignant disease is adequate surgical excision before the appearance of extension or metastasis. Since lung tissue is one of the more common sites of metastasis, radiologic examination of the thorax is one of the essential examinations of a cancer patient. Too frequently surgical intervention is abandoned on the premise that the presence of a pulmonary metastasis renders the prognosis hopeless. There is evidence at the present time to indicate that this conclusion is not always justifiable. It now appears likely that tumors have been removed in which there was evidence of a solitary lung metastasis and a cure was effected. The pulmonary lesion may have been present before initial surgery or detected at a much later date. Subsequent excision of the secondary lung tumor in a few of these patients has yielded promising results.

The term "solitary metastasis" is used in the broad sense. Actually, it is intended to mean that only one metastasis could be demonstrated at the time that excisional surgery was contemplated. Undiscovered and asymptomatic lesions may be present and assert themselves later.

REVIEW OF LITERATURE

A review of the literature to date reveals little information on the subject of surgery for the solitary lung metastasis. Due to the paucity of reported cases it must be assumed that there have been very few successful attempts to extirpate both a primary malignant tumor and associated solitary lung metastasis.

The outstanding case report of its kind is that submitted by Barney and Churchill in 1938 and again in 1944. This patient was subjected to operation in April, 1932, for an adenocarcinoma of the kidney. One year before operation a nodule in the left lung was detected by roentgenogram, and observation revealed a gradual increase in its size. X-ray therapy was employed following nephrectomy in an effort to obliterate the pulmonary lesion, but without apparent change. On July 18, 1933, thoracotomy was performed by Dr. E. D. Churchill, and approximately two-thirds of the left upper lobe was removed. The patient made an uneventful recovery from this procedure, and has been reported as alive and well thirteen years later. In 1943, Brezina and Lindskog reported a successful pneumonectomy in a 65-year-old woman, who is believed to have had a metastasis from an adenocarcinoma of the uterus. This case is of particular interest since the patient had been subjected to a hysterectomy thirteen years earlier. At the time of her first operation, the gross diagnosis of uterine carcinoma was offered, although no microscopic studies were made. The removed lung showed a solitary metastasis of uterine adenocarcinoma. In 1941, Raine

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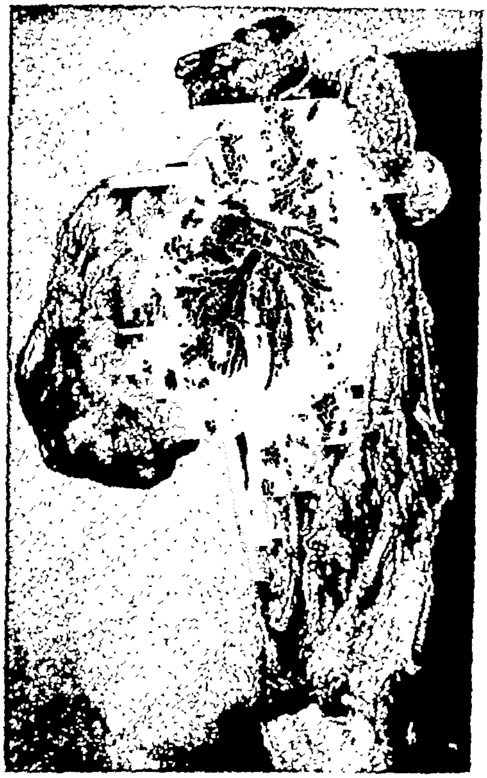

Fig. 1.—Case 1. Reproduction of specimen following supracondylar amputation of right leg. The normal soft tissue of the posterior leg has been dissected away, exposing the primary tumor mass which is identified microscopically as malignant synovioma.

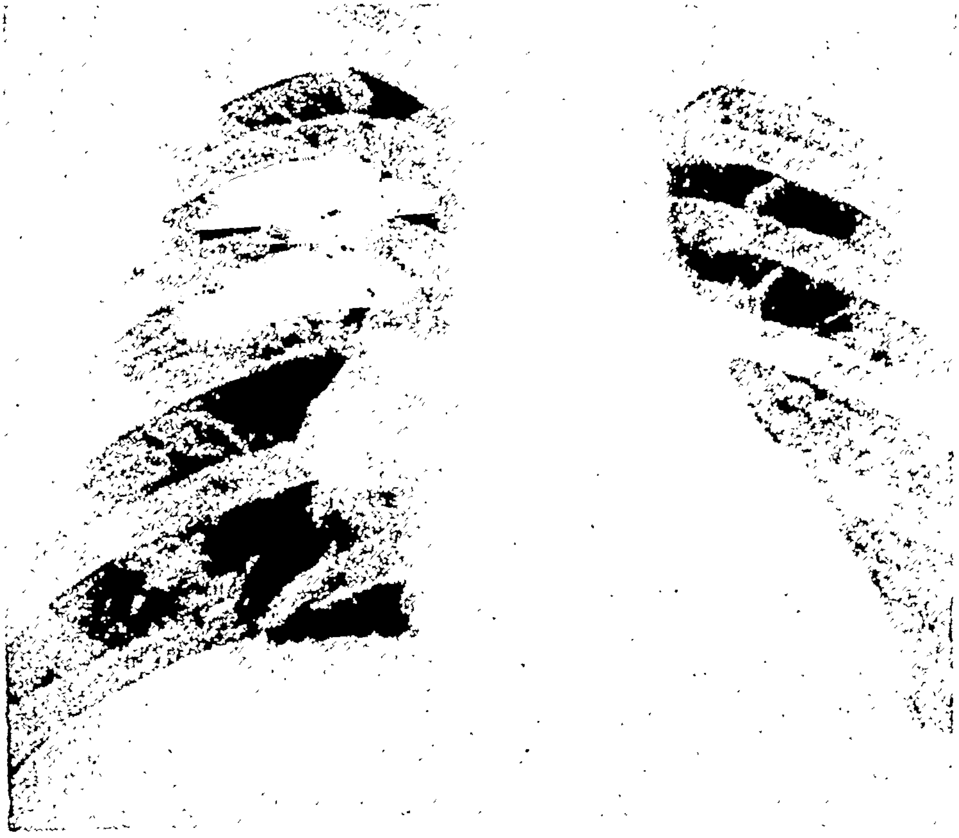

Fig. 2.—Case 1. Reproduction of roentgenogram made before amputation. The large solitary metastasis of the right middle lobe is clearly evident.

reported a successful pneumonectomy that was performed for a solitary metastasis invading the right main-stem bronchus. The primary source of this tumor was in the rectum, which had been removed eight months prior to admission. At the time of this case report, the patient gave evidence of involvement of the tumor elsewhere in the body. Blalock has two cases in which the patient has apparently benefited by extirpation of a solitary lung metastasis. In September, 1943, he performed a right total pneumonectomy on a 57-year-old man who had evidence of a tumor in the right lower lobe. Microscopic studies revealed the lesion to be a metastatic tumor, adenocarcinoma of the rectum. This patient had been subjected to bowel resection for the primary tumor in 1939. Blalock's second case is more remarkable in that the patient is 69 years of age. In December, 1942, she was operated upon at the Johns Hopkins Hospital and a resection of the cecum for carcinoma was performed. Several years later she developed symptoms of pulmonary disease and returned for re-examination. Roentgen studies revealed the presence of a tumor in the left lung. This lesion was discovered in August, 1946, approximately six months after the onset of her pulmonary symptoms. A left total pneumonectomy was performed in

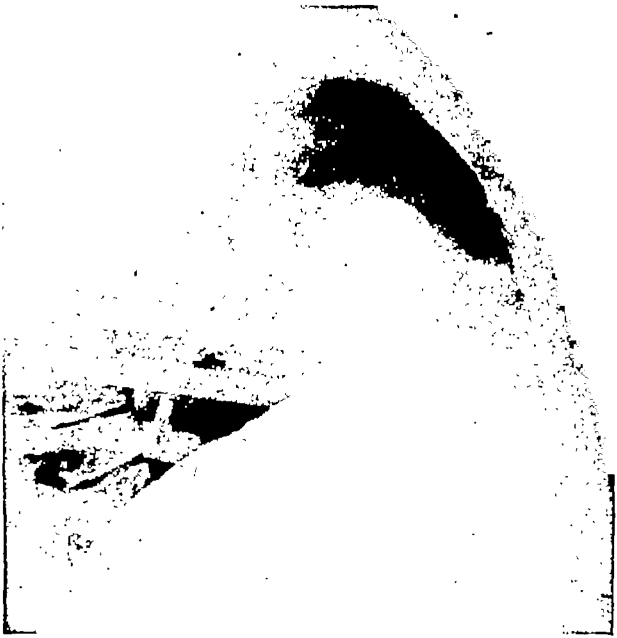

Fig. 3.—Case 1. Lateral view shows the anterior position of the solitary metastasis in the right middle lobe.

December, 1946, and the patient made an excellent recovery. Tissue studies confirmed the diagnosis of a metastatic tumor arising from an adenocarcinoma of the cecum. Five months have elapsed since operation, and the patient appears to be in good health. In October, 1946, Flick operated upon a 36-year-old woman for a solitary tumor of the right middle lobe. The patient had complained of hemoptysis of six weeks' duration prior to operation and roentgenogram of the lung fields revealed the presence of the round neoplasm which measured 4 cm. in diameter. In 1938, the patient had been subjected to excision of a mass in her left thigh. The tissue diagnosis of liposarcoma was established. There were no local recurrences or distant metastases noted until the appearance of the pulmonary lesion eight years later. After lobectomy the diagnosis of metastatic liposarcoma was confirmed. The patient's immediate postoperative course was uneventful and at the present time she appears to be in excellent health.

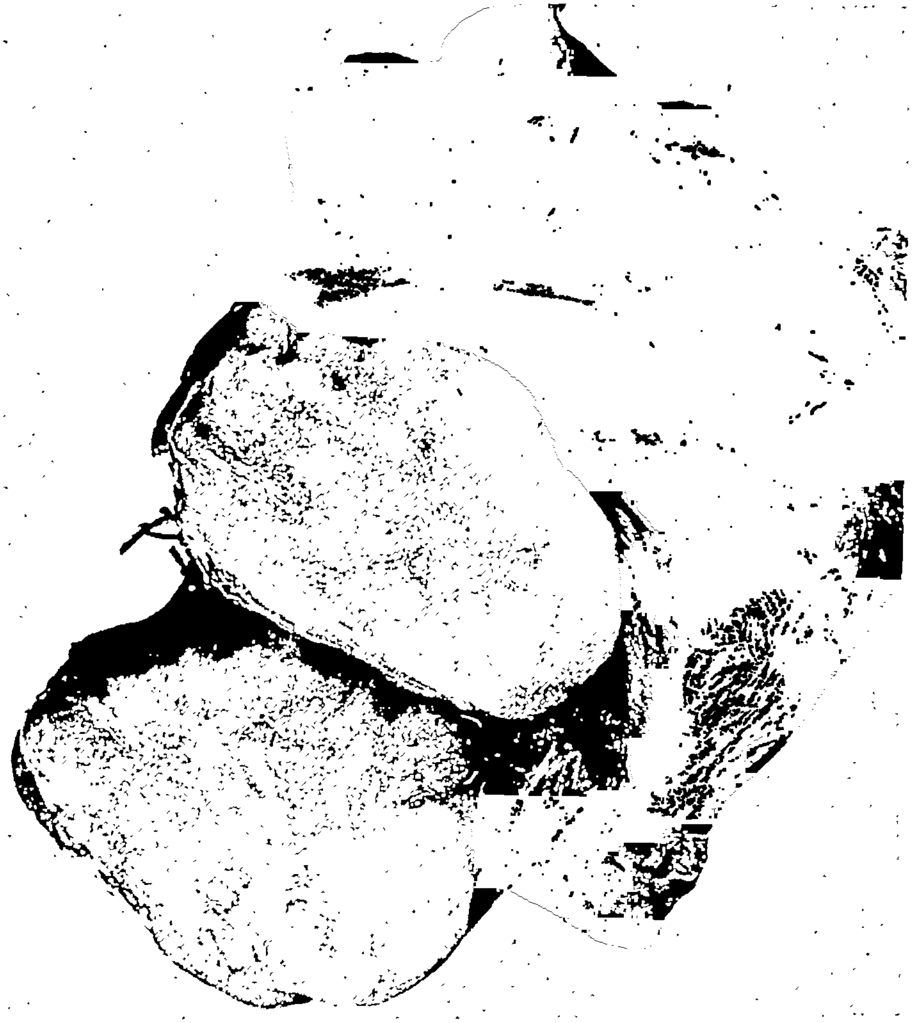

Fig. 4.—Case 1. The right middle lobe as it appeared immediately after operation. The solitary metastasis has been sectioned for tissue diagnosis.

CASE HISTORIES

Three case histories are presented at this time because of their unusual interest. In each case, the primary tumor was identified and successfully removed. One patient had a solitary lung metastasis at the time of his admission. The other two developed solitary pulmonary lesions after discharge from the hospital. In each case the solitary lung metastasis was removed with apparent benefit to the patient.

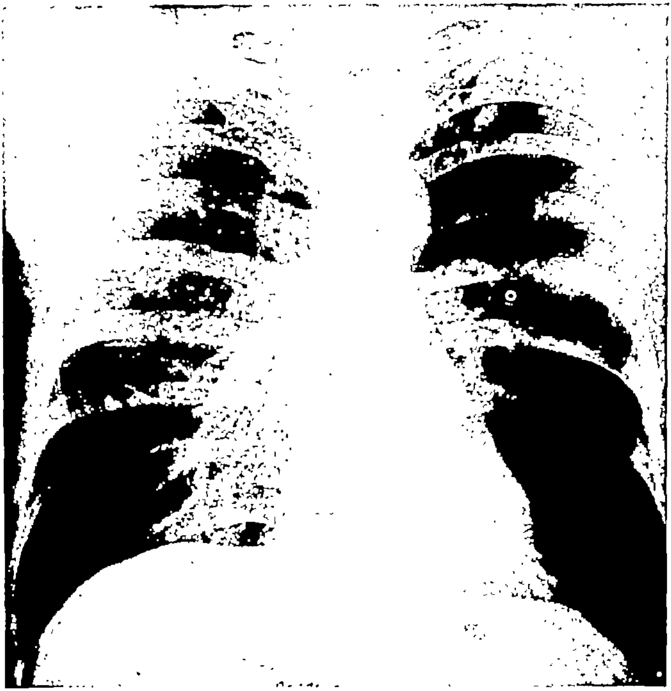

Fig. 5.—Case 2. A roentgenogram of the chest made in September, 1944, one month prior to bowel resection for adenocarcinoma of the sigmoid colon. There is no evidence of pulmonary metastasis demonstrated.

CASE 1.—A 23-year-old white soldier was admitted to the Walter Reed General Hospital on Aug. 22, 1945. The chief complaint on admission was a painless mass in the calf of his right leg. In 1943 he first noted that the right leg was slightly larger than the left. The swelling gradually increased until February, 1945. The past history was of interest in that he was hospitalized one week in July, 1944, for a sharp pain in the right chest, but there was no cough or sputum. Examination on admission showed marked enlargement of the right calf. The involved area was firm and showed skin striae. The right calf measured 20¾ inches and the left calf about 15 inches. Roentgen studies revealed a huge tumor extending

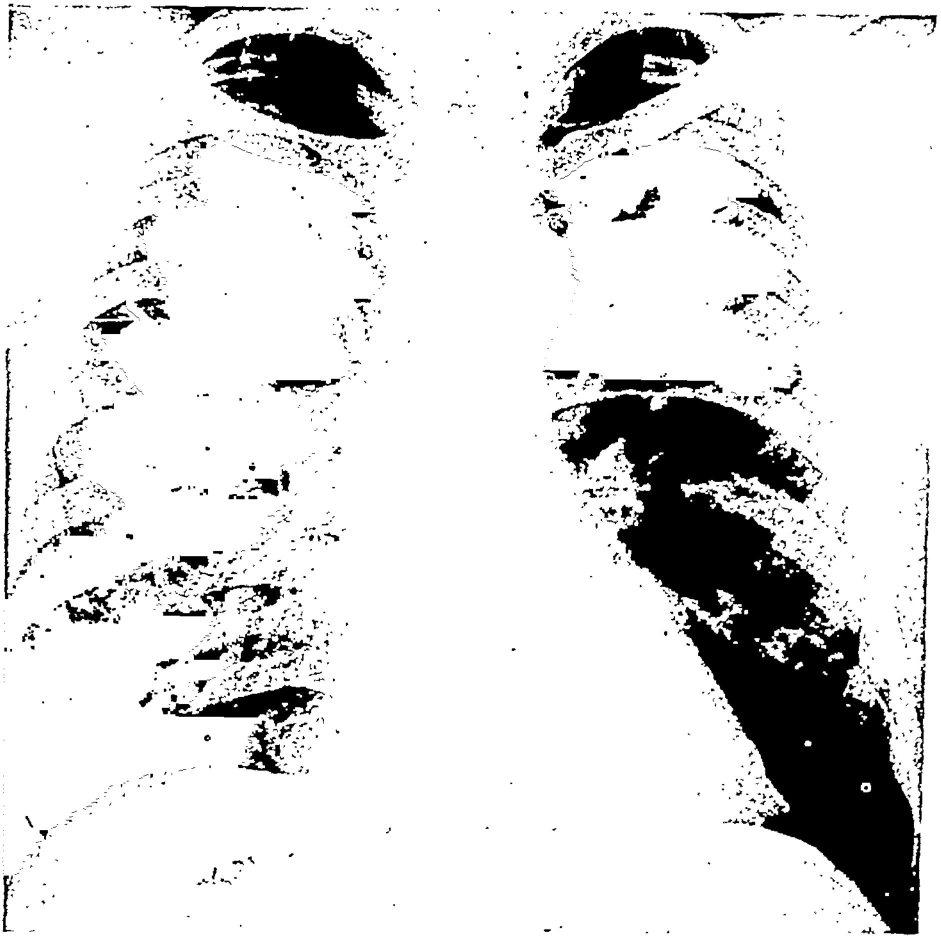

Fig. 6.—Case 2. Roentgenogram made in August, 1946, at the Walter Reed General Hospital. The solitary metastasis in the right upper lobe is easily identified.

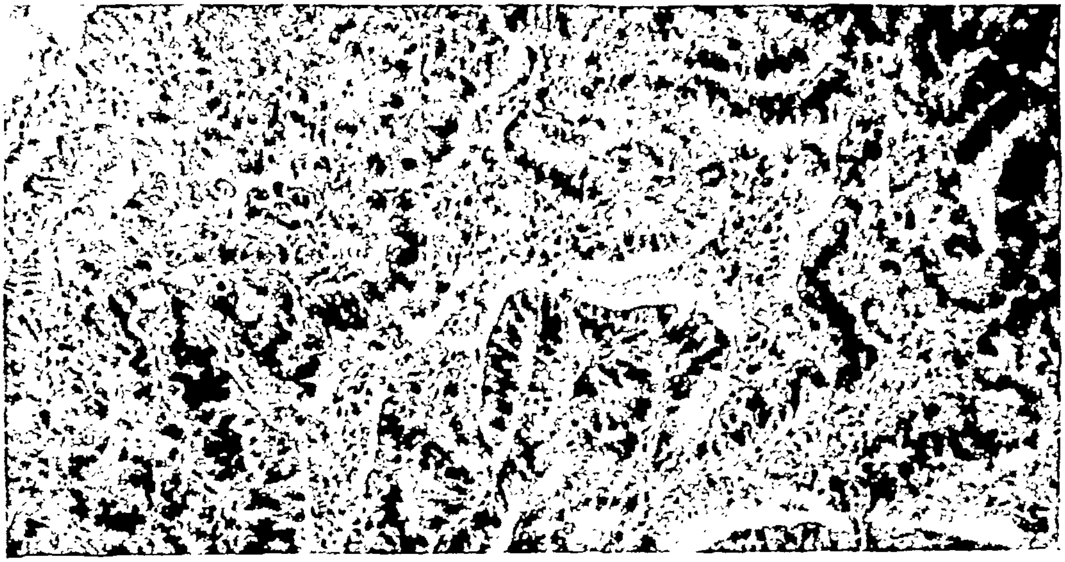

Fig. 7.—Case 2. A photomicrograph made from the solitary metastasis of the right upper lobe. Pathology diagnosis is adenocarcinoma, metastatic, from the large bowel.

from the popliteal space to a point 26 cm. below the knee joint. There was extensive calcification of the mass. The tibia and fibula appeared to be normal. Examination of the chest revealed a solitary lesion about 4 cm. in diameter that appeared to be in the right middle lobe. On Sept. 4, 1945, a supracondylar amputation of the right leg was performed. The tumor was found to be a lobulated mass that was fairly well encapsulated. There was evidence of infiltration of the neoplasm into the tibial vein. The final diagnosis was malignant synovioma with infiltration of the posterior tibial vein. On Nov. 7, 1945, an exploratory thoracotomy was performed. The principal finding at operation was a tumor mass that was localized to the right middle lobe. There was no palpable or visible evidence of other metastases. A right middle lobe lobectomy was performed. The diagnosis of metastatic synovioma was confirmed by the tissue study. This patient made an uneventful recovery from both procedures and was fitted for a prosthesis for his amputation. Careful studies revealed no evidence of other metastases or local recurrence. He was separated from the service in March, 1946. It is seventeen months since pulmonary resection and this patient appears to be in good health.

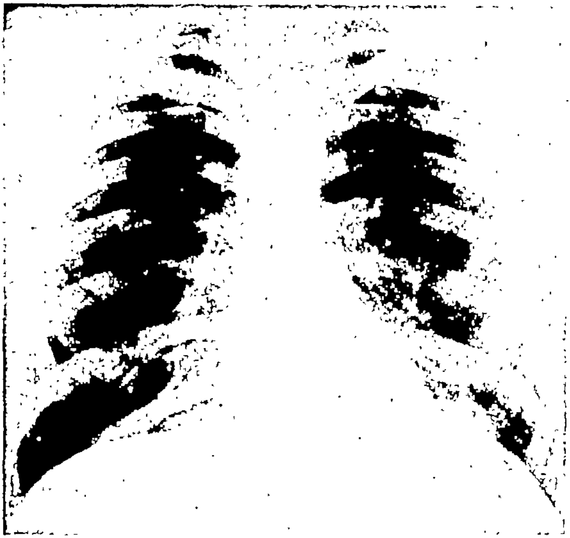

Fig. 8.—Case 3. Roentgenogram of the chest showing large solitary metastasis in left lower lobe.

Case 2.—The patient, a 51-year-old officer, was admitted to Walter Reed General Hospital on July 24, 1946. He was admitted primarily for administrative reasons after serving eighteen months of temporary limited duty. According to the patient, he had been hospitalized in September, 1944, because of lower abdominal cramps and the presence of bright red blood in the stools. After thorough examination, the diagnosis of an annular malignant lesion of the sigmoid bowel was established. On Nov. 18, 1944, the patient was operated upon. The lesion was excised with an end-to-end anastomosis of the colon. Exploration of the abdomen revealed no evidence of metastasis in the liver, aortic lymph nodes, or adjacent viscera. The pathologic diagnosis was adenocarcinoma of the sigmoid. This man made an uneventful postoperative recovery. Roentgenogram studies of the thorax were obtained and the lung fields appeared to be normal. On Jan. 19, 1945, the patient returned to limited duty. He was readmitted on July 23, 1945, for a complete physical examination, including a roentgenogram of the chest. The officer states that he enjoyed excellent health and performed all duties without incident until he was recalled in January, 1946, for examination, and re-evaluation. At this time a small, nodular lesion was detected on the roentgen film and reported as being in the right upper lobe. The patient remained under observation until his admission to Walter Reed General Hospital in July, 1946. Careful examination revealed no evidence of local recurrence of the neoplasm or metastasis other than the solitary lesion in the right upper lobe. A careful review was made of all the chest films that had been made since his entrance to active duty in 1942. The presence of a solitary metastasis was strongly suspected and surgical exploration was advised. The patient was operated upon Sept. 16, 1946, and an exploratory thoracotomy was performed. The lesion was easily identified in the right upper lobe and tissue was obtained for biopsy. Frozen section examination was reported as showing adenocarcinoma, probably metastatic. A right upper lobe lobectomy was performed and the patient made an uneventful recovery. Following operation a complete survey was made to uncover any other possible metastasis or recurrence of the original tumor. This survey included physical examination and roentgen studies of the thorax, skeletal system, gastrointestinal tract, and the

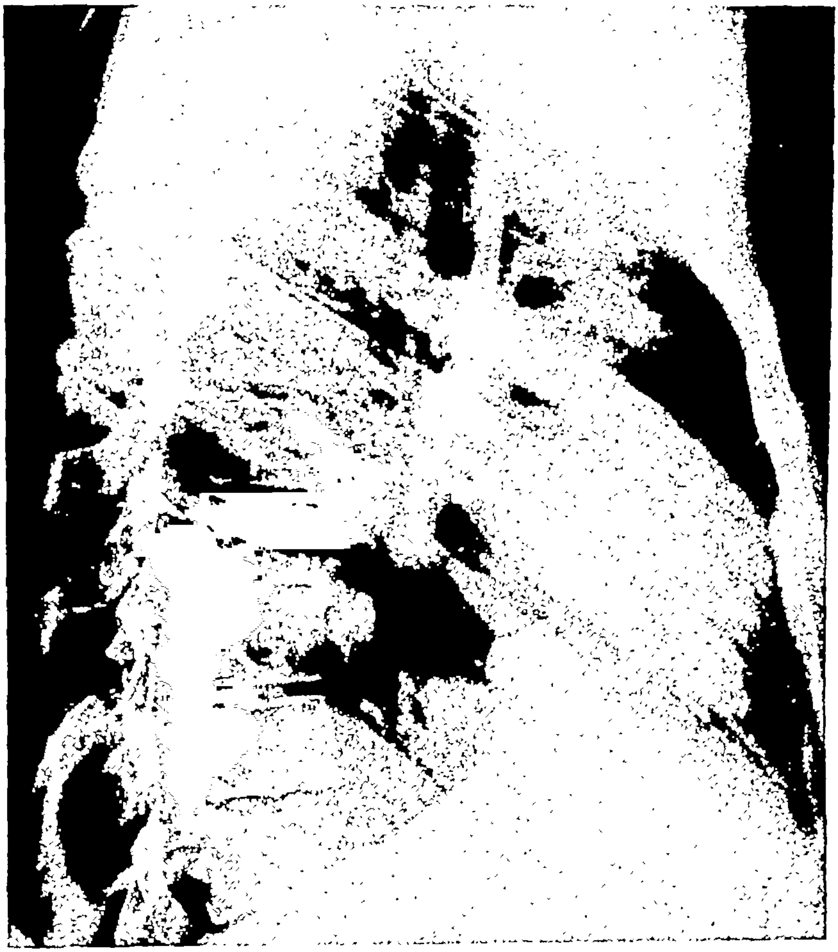

Fig. 9.—Case 3. Lateral view showing position of tumor in left lower lobe.

urinary system. At that time, there was no evidence to suggest the presence of disease. The final report from the department of pathology was *adenocarcinoma, metastatic, probably from bowel.* In February, 1947, the patient returned to the Walter Reed General Hospital with clinical evidence of an intercranial tumor. Craniotomy was performed and the lesion removed. In the gross examination the tumor appeared identical to the pulmonary lesion. Microscopic studies revealed that it, too, was adenocarcinoma, metastatic, probably from the large bowel. The patient has recovered from this second procedure and appears to be perfectly well. He has been released from the Army and has returned home, where he plans to resume his civilian occupation.

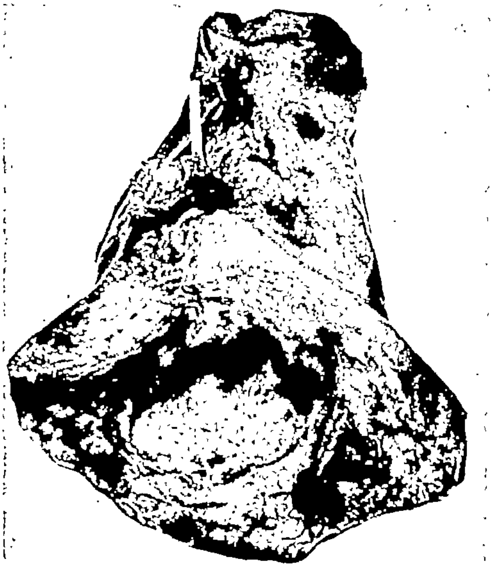

Fig. 10.—Case 3. Photograph of left lower lobe immediately following lobectomy. The tumor mass can be seen underlying the visceral pleura on the diaphragmatic surface of the lobe.

CASE 3.—The patient is a 20-year-old white man who was first admitted to the Walter Reed General Hospital in August, 1945. Prior to this admission he had been on overseas duty in the Pacific theater. In May, 1945, he first noted gradual enlargement of the left testicle. Following hospitalization, the impression of testicular tumor was made and confirmed by simple orchidectomy. Microscopic tissue studies were made in an army hospital in the Philippine Islands. The reports accompanying the patient gave the diagnosis of malignant testicular tumor, probably seminoma. The original specimen did not accompany the patient during evacuation to the Zone of the Interior. Following admission to Walter Reed General Hospital, complete physical examination was essentially normal. On Sept. 8, 1945, a radical gland dissection was performed to clean out the left iliac and abdominal retroperitoneal nodes. Careful microscopic studies of all removed lymph nodes failed to demonstrate tumor tissue. After recovery from this procedure, the patient received intensive million-volt roentgen therapy to all the retroperitoneal lymph glands as prophylactic treatment. Radiation therapy was completed in November, 1945, and the following month the patient was discharged from the hospital and separated from military service. He states that he felt very well and returned to his former civilian occupation. In March, 1946, he reported back to the Walter Reed General Hospital for periodic examination. At this time a small round mass in the left lower lobe was demonstrated by roentgen examination of the thorax. It was the impression of the roentgenologists that this represented a metastasis from a probable seminoma and as such it would be very sensitive to radiation therapy. The patient received treatment with a total dose of 2,200 volts and remained under observation until October, 1946. The neoplasm did not respond to radiation therapy but continued to grow until it was the size of a hen's egg. When seen by the thoracic surgical consultant, the patient appeared to be in excellent health and had no complaints other than vague discomfort in the left shoulder. There was no evidence of other metastases. On Oct. 24, 1946, exploratory thoracotomy was performed. A firm tumor which did not invade the visceral pleura was found in the periphery of the left lower lobe. In addition, there was a single hard lymph node invading the wall of the inferior pulmonary vein. No other evidence of neoplasm was discovered. A left lower lobectomy was performed without difficulty and the patient made an uneventful postoperative recovery. Microscopic diagnosis of the tumor and the involved lymph node was teratocarcinoma with chorionepithelioma component metastatic from testicular tumor. Approximately four months after operation the patient returned with clinical evidence of brain and skull metastases. Although no tissue biopsy has been obtained, it is evident that the patient has an extensive metastatic process at this time.

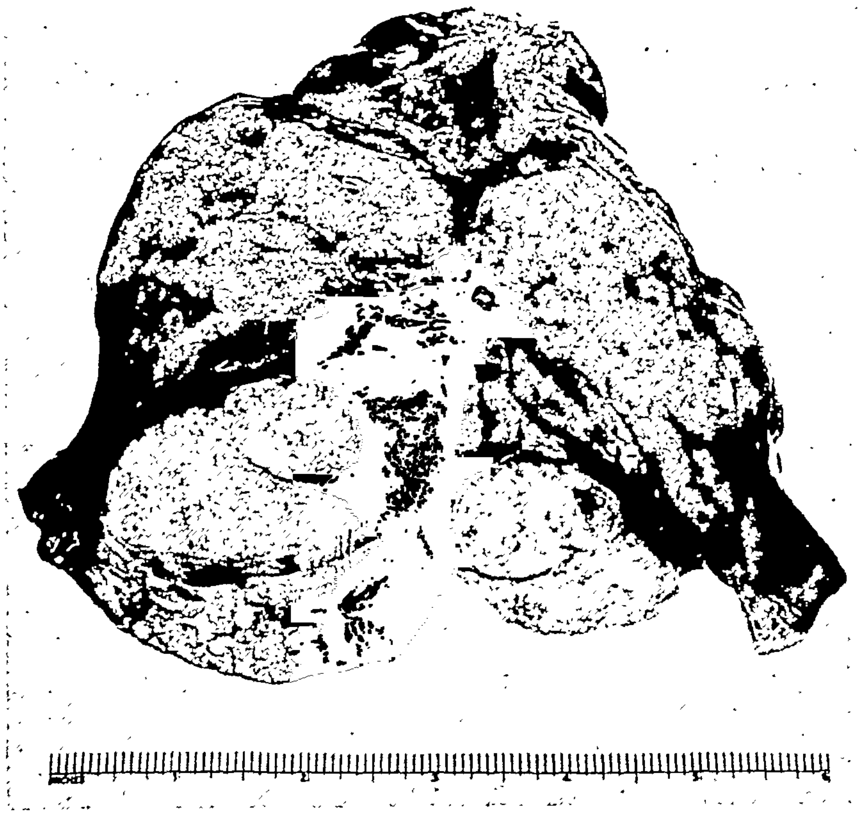

Fig. 11.—Case 3. Photograph of specimen after sectioning.

RÉSUMÉ OF CASES OF SOLITARY METASTASIS REPORTED IN THE LITERATURE

CASE	TYPE OF PRIMARY TUMOR	SURGEON	APPEARANCE OF METASTASES	DATE OF OPERATION	PRESENT CONDITION
1	Renal adenocarcinoma	Churchill	12 months prior to pneumonectomy	April, 1932	Living and well
2	Uterine adenocarcinoma	Lindskog	13 years after hysterectomy	1943	Living and well
3	Carcinoma of rectum	Raine	8 months after excision of rectum	1941	Dead: visceral metastases nine months after pneumonectomy
4	Adenocarcinoma of rectum	Blalock	4 years after bowel resection	March, 1943	Living and well
5	Adenocarcinoma of cecum	Blalock	3½ years after bowel resection	Dec., 1946	Living and well
6	Malignant synovioma	Blades	Present at time of amputation primary tumor	Nov., 1945	Living and well
7	Adenocarcinoma of colon	Effler	18 months after bowel resection	Sept., 1946	Solitary metastasis in brain removed Feb. 1947. Apparently well now
8	Liposarcoma of thigh	Flick	8 years after excision of primary	Oct., 1946	Living and well
9	Teratocarcinoma of testis	Effler	7 months after gland dissection of retroperitoneal nodes	Oct., 1946	Evidence of skull and cerebral metastases

CONCLUSION

The surgical treatment of the solitary lung metastasis is indicated in specific instances. It would seem reasonable that excisional therapy is indicated where the primary tumor has been extirpated and careful search reveals no manifestations of extension other than the solitary metastasis. It has been pointed out by Beers, and later by Bumpus, that metastases have been known to regress and disappear following removal of a primary renal carcinoma. This is an interesting and little understood phenomenon, but certainly it should not be considered a contraindication of surgery for the solitary metastasis. Likewise, it has been observed that solitary metastasis may appear early or very late, as much as ten years following removal of the primary tumor. It is difficult to understand why the development of the late metastasis is delayed; however, it is reasonable to assume that the chance for a cure in excision of the solitary metastasis would be better when the metastasis appears late.

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EXTRAPLEURAL PNEUMOTHORAX

A Late Follow-Up of Eighty-Two Patients Upon Whom Ninety-two Operations Were Performed

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EXTRAPLEURAL pneumothorax was first introduced as a method of surgical collapse for pulmonary tuberculosis by Tuffier in 1910. It was not widely used until Graf of Dresden in 1932 published a series of good results. Like most new surgical procedures, it was greeted with great enthusiasm and many operations were performed before sufficient experience had been gained in the selection of cases. Because of the frequency of complications, this enthusiasm has waned until it is now used infrequently in most sanatoriums. In June, 1940, a symposium on this procedure was held by the American Association of Thoracic Surgeons. In the discussion, doubts were expressed that the late results would be as satisfactory as the early.

This study is based on ninety-two extrapleural operations performed on eighty-two patients from October, 1937, to August, 1945. The time that has elapsed since operation varies from one year and six months to eight years, but the majority of patients have been followed five years or longer. With the exception of one patient, x-ray films of all were studied, lesions were classified, and progress reviewed. One patient is an Indian squaw, and as we have reports on her progress five years after her operation, she has been included. Age at the time of operation varied from 12 to 62 years. The 62-year-old patient is now 67 and working part-time. The pneumothorax was on the right side alone thirty-seven times, on the left side alone thirty-five times, and bilateral in ten cases.

SELECTION OF CASES

No minimal cases were operated upon. The cases have been classified according to the National Tuberculosis Association classification as moderately and far advanced. Whether very far-advanced conditions should be operated upon is a controversial subject. In order to obtain information on this point, desperate risk patients with very extensive involvement or in poor clinical condition have been grouped together as a separate division, namely, "very far advanced."

Discussion.—(a) Very far advanced: While it is true that only one out of sixteen has been returned to full-time work, seven of these desperate cases have survived to date. This indicates that perhaps it was worth while subjecting the whole sixteen to operation. An example of this group is seen in Fig. 1.

(b) Far and moderately advanced: On reviewing the films today almost all the patients would have been suitable for a well-planned thoracoplasty and this would have eliminated the later hazards of the residual extrapleural space. A possible exception is illustrated in Fig. 2. This patient is an actress in whom a

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TABLE I.—PRESENT STATUS OF PATIENTS

	MODERATELY ADVANCED		FAR ADVANCED		VERY FAR ADVANCED		TOTAL	
	NO.	%	NO.	%	NO.	%	NO.	%
Deaths	4	11.7	9	28.1	9	56.2	22	26.8
Working full time	15	44.1	9	28.1	1	6.2	25	30.5
Working part time	6	17.6	4	12.5	2	12.4	12	14.6
Unfit for work	4	11.7	9	28.1	3	18.7	16	19.5
Other treatment necessary	5	14.7	1	3.1	1	6.2	7	8.5
Totals	34	100	32	100	16	100	82	99.9

thoracoplasty with its resultant scar and deformity would have made it difficult if not impossible for her to earn a living.

Analysis of Deaths.—In this series of eighty-two patients, twenty-two have died (26.8 per cent). The average survival time was two years and three months. The latest died six years and nine months after operation. The deaths have been divided into early (those occurring within six weeks of operation) and late.

Early Deaths (Four).—One died of hemorrhage into the extrapleural space on the night of the operation. In one a large cavity was opened into at operation and bronchopleurocutaneous fistula and tuberculous cellulitis resulted and death occurred one month postoperatively. Another died one month after the operation from tuberculous colitis with fistula formation and generalized peritonitis. The fourth death occurred from rapid progression of tuberculous bronchopneumonia on the other side.

Late Deaths (Eighteen Cases).—(a) Ten patients died from progressive pulmonary tuberculosis due to unsatisfactory collapse obtained by extrapleural pneumothorax with subsequent spread of the disease and often enteritis.

(b) One patient succumbed to extension of disease on the opposite side despite a good collapse obtained on the extrapleural side.

(c) Four died as a result of bronchopleural fistula, three of them from pulmonary tuberculosis (Fig. 3), and one of a staphylococcus pneumonia and empyema the result of a spontaneous pneumothorax following aspiration for fluid.

(d) Miliary tuberculosis, hemorrhage from peptic ulcer, anoxemia of doubtful etiology each accounted for one death. These were verified by autopsy.

Present Status of Extrapleural Space.—There are sixty-seven extrapleurals on sixty living patients.

(a) Space maintained with air — 32.
(b) Space maintained with oleothorax — 19.
(c) Alive with re-expansion of lung — 4.
(d) Alive with persistent fluid usually positive — 5.
(e) Alive with further treatment on the extrapleural side — 7.

DISCUSSION

It is our belief that extrapleural spaces are best maintained by air refills. The disadvantage is the necessity of the patient's returning indefinitely but the fluid, which forms so frequently, can usually be easily controlled by increasing the pressures or decreasing the interval, provided it is recognized early.

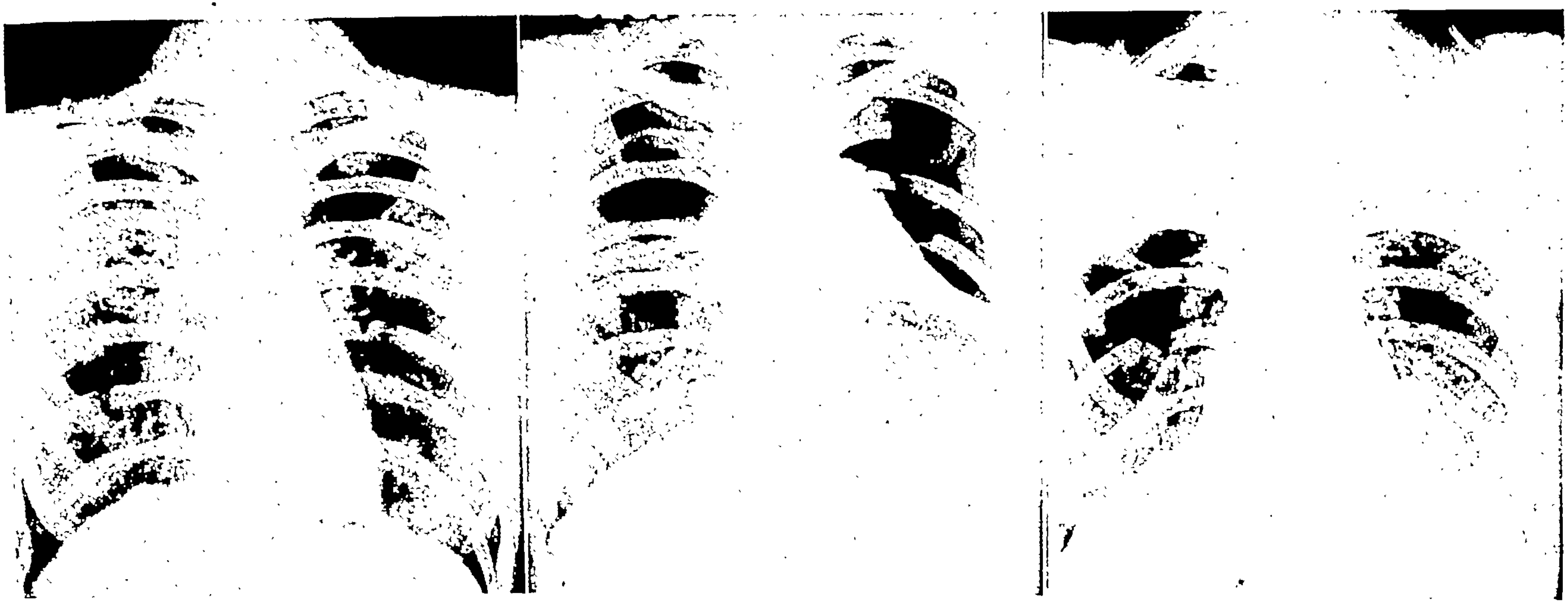
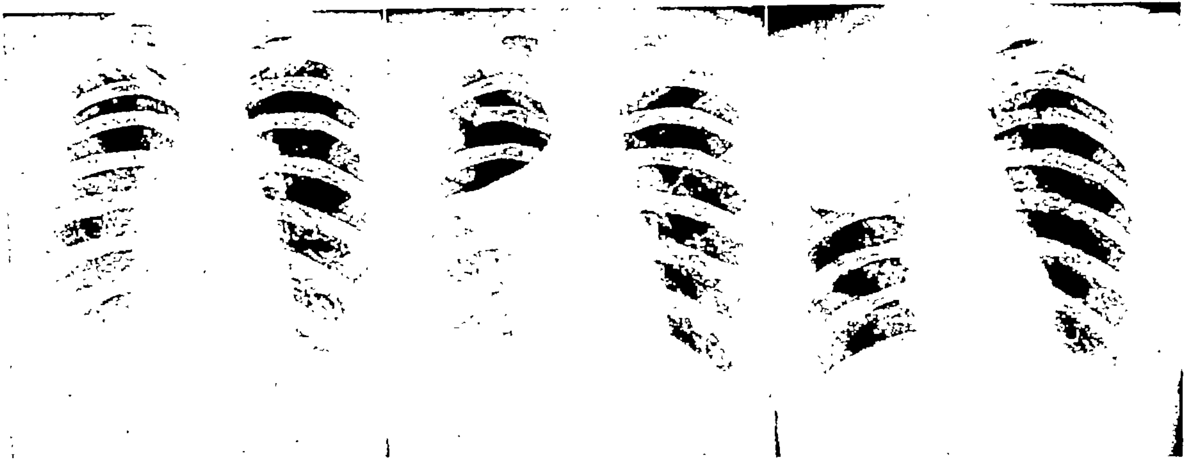


Fig. 1.—F., 34 years of age, was admitted June 5, 1938, with moderately advanced pulmonary tuberculosis, active bacillary. Pneumothorax was inefficient. The disease continued to spread and several hemorrhages occurred. Right extrapleural was done Feb. 5, 1941, and left extrapleural April 7, 1943. Present status is clinically well, sputum occasionally positive.

A, Before extrapleural pneumonolyses.
B, After bilateral extrapleurals.
C, After oil replacement.



A. B. C.

Fig. 2.—F., 43 years of age, was admitted Aug. 18, 1941, with moderately advanced pulmonary tuberculosis, active bacillary, and history of right-sided pleurisy. An actress, she was most anxious to avoid thoracoplasty. Right extrapleural was done Sept. 3, 1941. Present status is clinically well, no sputum. She recently circled the globe entertaining British troops.

A, Shortly after admission.
B, Following extrapleural.
C, After oil replacement and five-year follow up.

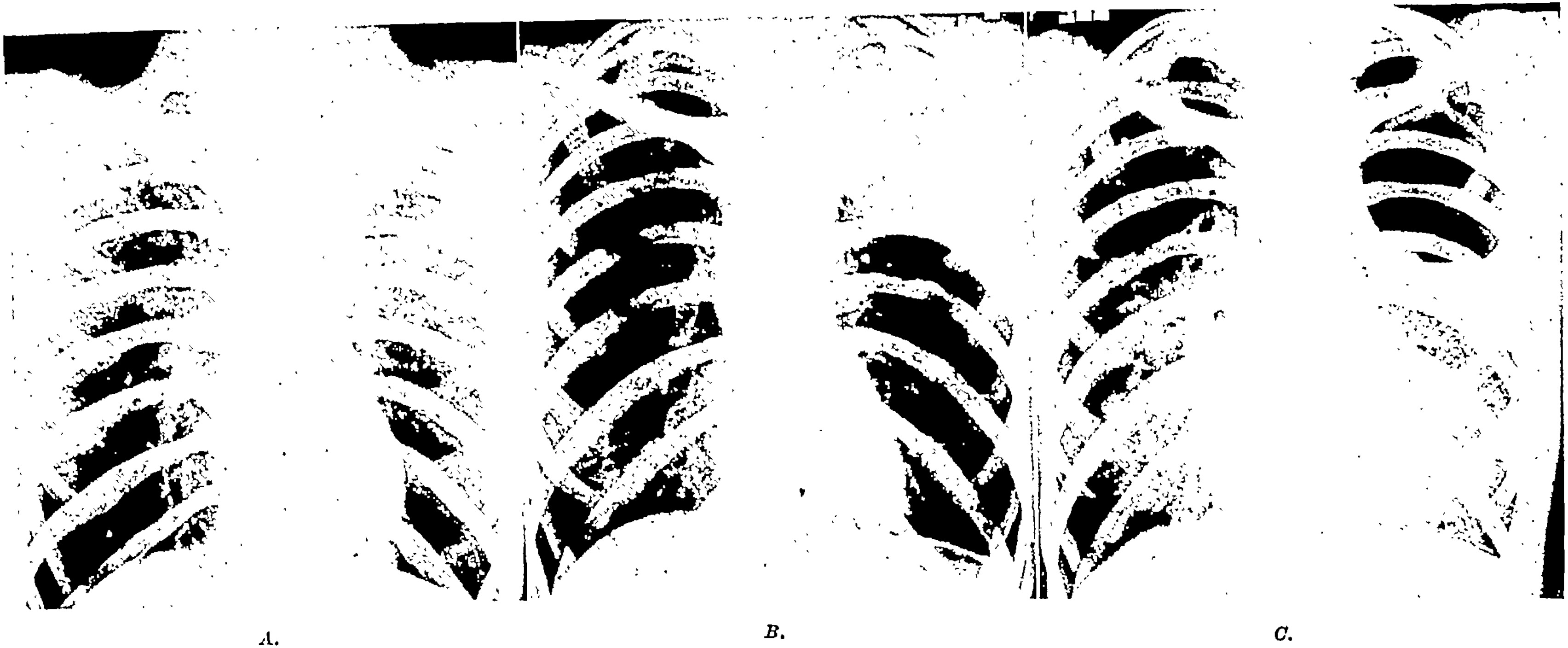


Fig. 3.—F., 33 years old, was admitted June 19, 1939, with far advanced pulmonary tuberculosis, active bacillary. Planograms showed large cavity in left apex. Left extrapleural was done Nov. 1, 1941. Fluid postoperatively cleared with irrigations and was replaced with oil. Discharged Feb. 22, 1941, clinically well and sputum free.

Regular check-ups elsewhere without oil samples being taken. In Oct., 1944, she developed cough and sputum and two weeks later bronchopleural fistula. Readmitted Nov. 26, 1944, with extensive spread of disease, and died.

A, Before extrapleural.
B, Radiograph a few weeks prior to developing fistula.
C, After readmission.

Many patients with oil replacement have done well but tuberculous fluid may form with the oil. Radiologically and clinically this cannot be recognized until it attains a sufficient pressure to rupture into the lung (Fig. 3). If oil has been put into the extrapleural space, it seems safer to aspirate a sample every six months for tuberculosis culture to avoid this catastrophe.

It is generally recognized that an extrapleural pneumothorax results in a permanent collapse, although in the literature as late as April, 1943, this statement is found, "Every successful extrapleural pneumothorax reported is a patient saved from thoracoplasty and given the benefit of temporary collapse." Only four out of ninety-two (4.7 per cent) of our patients have re-expanded lungs. Ill-advised attempts to re-expand these lungs result almost invariably in the formation of an extrapleural empyema.

Further Treatment. —Seven patients have required further surgical treatment on the same side. Five have had thoracoplastics; three because of tuberculous empyemas and two because of insufficient collapse and persistently positive sputum. One of the latter has not been converted.

Two have had pneumonectomies for persistently positive sputum. One is well and her sputum is negative; the other is well clinically but sputum is still positive, presumably from an ulcer of the bronchial stump.

CONCLUSION

1. Considering the type of case chosen, the results of extrapleural pneumothoraces in this series were reasonably satisfactory. Despite this fact, the procedure is thought to have a very limited place in the surgical therapy of pulmonary tuberculosis.

2. The operative mortality was higher than that of thoracoplasty but was due at the beginning to inexperience in the performance of the operation and in postoperative management.

3. The patients require care of a difficult kind indefinitely and are always liable to develop unpleasant complications.

4. The present view is that this procedure should usually be reserved for young, growing individuals who would probably develop considerable deformity following thoracoplasty and for a small group in whom the scar and deformity of thoracoplasty would debar them from a special vocation.

These operations were performed at the Toronto Hospital for Tuberculosis and I am indebted to Dr. Robert Janes and Dr. F. G. Kergin, Consultants on the Thoracic Surgical Service, and to Dr. M. J. McHugh, Medical Superintendent, for the privilege of making this report. I should also like to express my gratitude to Miss M. O'Sullivan, Record Librarian, for the difficult task of following the patients.

AN EXPERIMENTAL STUDY OF THE EFFECT OF LIGATION OF PULMONARY VEINS IN THE DOG

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IN THE course of experiments designed to explore the possibility of creating a venous shunt between the systemic and pulmonary venous systems, it became desirable to utilize the proximal end of a divided pulmonary vein to one lobe in an end-to-end anastomosis. This would necessitate ligation of the distal end of the divided pulmonary vein to the lobe and would, in effect, be exactly equivalent to simple ligation of the pulmonary vein in so far as subsequent changes in the lobe itself are concerned. We wished to know, therefore, what changes in a pulmonary lobe are to be expected following simple venous ligation. In turning to the literature for the answer to this problem, we were surprised to find that, so far as we could discover, this simple experiment had never been fully exploited, and the answer was not fully known. Accordingly, a series of dogs were subjected to simple total ligation of the pulmonary vein from the upper lobe of the right lung and the subsequent pathologic changes in the lobe were observed at different time intervals following operation.

REVIEW OF THE LITERATURE

Interest in pulmonary vein ligation first arose because it suggested itself as a therapeutic method in the treatment of tuberculosis. Tiegel's work,[1] published in 1911, has been offered as evidence that advanced pulmonary fibrosis is the end result of pulmonary vein ligation. However, in reviewing this study, it was apparent that Tiegel was not attempting complete venous ligation. He described placing silver wire rings around the pulmonary veins of rabbits and dogs to partially obstruct their lumina. In animals which survived, this was followed by an immediate intense engorgement of the pulmonary capillaries, accompanied by pulmonary hemorrhage. After weeks or months, firm pleural adhesions were found containing many blood vessels, and there was thickening of the pleura and alveolar septa. The lobes were said to be smaller, paler, and firmer than the normal lobes on the opposite side. In only two of his animals was complete ligation performed, and he noted that in many of the lungs histologic changes were minimal. Kawamura[2] confined his studies in rabbits to ligation of the pulmonary *artery* to the left lower lobe. In 1923, Schlaepfer[3] reported on the clinicopathologic aspects of air embolism following minor or major intrapleural manipulations. Experimental observations on two dogs following partial ligation of the pulmonary vein on one side were described, with special attention to the development of collateral venous channels which

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developed through parietovisceral adhesions and through enlargement of the bronchial veins. This author's subsequent work was confined to the effects of pulmonary arterial ligation.[4, 5]

We believe that the first clinical cases with pulmonary venous ligation were those reported by Kerschner[6] in 1931. Four patients with tuberculous cavities in the upper lobes underwent this operative procedure with mildly encouraging but not spectacular clinical results. No pathologic studies were available at the time of the report. In 1932 appeared the careful experimental studies of Mathes[7] and co-workers on the bronchial, pulmonary, and lymphatic circulations of the lung under various experimentally produced pathologic conditions. Among other conditions investigated, complete ligation of the pulmonary vein to one lobe of the lung was usually, although not invariably, followed by death of the animal in four or five days. The pleural cavity was found to be filled with a thin blood-stained effusion and the lobe was large, *firm, and of a deep red, liverlike consistency. The bronchial artery appeared* normal; the pulmonary artery was injected poorly with bismuth mass because of peripheral venous congestion. The number of animals used and the particular lobe whose vein was ligated were not stated.

This work apparently escaped the attention of European surgeons, because O'Shaughnessy,[8] in 1935, published three clinical cases with vein ligation using the report of Tiegel as experimental background. His patients had been followed less than one year, and no pathologic observations were available. In the same year, Valkányi[9] reported on three experimental and five clinical cases with pulmonary vein ligation. He tied the vein to the upper or middle lobe of the lung in three dogs. The mortality was not stated. The pathologic changes seen three to five weeks postoperatively were described by Professor Jàrmay. There was moderate shrinkage and a firm consistency of the lobe. Microscopically confluent areas of fibrosis were seen; the pleura was thickened, the alveoli were smaller and contained hemosiderin-laden phagocytes. Of the five patients with tuberculous cavities, one died postoperatively, two were unimproved, and two demonstrated moderate healing.

The study reported in 1938 by Ameuille[10] and his co-workers was concerned chiefly with the development of collateral venous channels following pulmonary vein ligation. Ten dogs were operated upon transpleurally. Six died in the immediate postoperative period. The remaining four were sacrificed at six weeks, *four months, six months, and seven and one-half months, respectively.* The pulmonary vessels were studied by injection. Firm vascular adhesions developing at the operative site and between the pleura and the chest wall contained enlarged collateral venous channels. There was no change in the pulmonary artery, but the bronchial artery and the artery of the pulmonary ligament seemed slightly enlarged. No description of the tissue changes found in the lung was given.

In his description of a two-stage operation for pneumonectomy in 1938, Rienhoff[11] states that if the pulmonary veins were ligated in the first stage, wet gangrene supervened. The observations which formed the basis for this statement were not described.

It would appear, therefore, that there is conflicting opinion as to the fate of a lobe of a lung following ligation of its veins, and that the only available evidence is comprised of the three animals of Valkányi and the unknown number of animals used by Mathes and associates. Observations were made, therefore, at various postoperative periods on eleven dogs in which the venous return from a single lobe had been ligated and cut, and on two animals in which the entire pulmonary vein to one side was ligated and cut.

METHOD

Healthy mongrel dogs of medium or large size were used. In the performance of all surgical procedures, operating room technique and aseptic precautions were the same as used in the main operating room of the hospital. All procedures were done under endotracheal positive pressure ether anesthesia. Following operation, the animals were placed in individual cages until fully recovered, and then returned to the kennel runs. In the protocols, the term ligation will be used throughout to mean double ligation and complete division of the vessel. The postmortem tissues were fixed in 4 per cent formaldehyde, washed in tap water, cleared by dioxane, imbedded in paraffin, cut at 8 microns thickness, and stained by hematoxylin and eosin, Turnbull's blue, and Weigert's elastic tissue stain. Each animal served as its own control. In all cases none of the nonoperated lobes of the right lung and none of those of the left lung showed changes comparable to those observed in the lobes whose veins were ligated and severed. The necessity for dummy control operations was, therefore, eliminated.

PROTOCOLS

I. Single Lobe Ligations

Dog number V-1.—A stocky, slick-haired, brown dog weighing 22 kg.

May 24, 1946. Operation. Ligation of veins to right upper lobe.

May 27, 1946. Dog appears well but has moderate cough, with thick mucoid sputum.

May 31, 1946. Reoperation. Right upper lobe appears a deep dull red in color; is very firm, and feels solid. Lobe removed as a specimen. Middle lobe utilized for a different experiment, then removed. Lower lobe veins ligated. Moderate shock.

June 1, 1946. Dog found dead.

Autopsy.—Moderate amount of reddish exudate in pleural cavity. Right lower lobe solid, very hemorrhagic. Left lung normal.

Microscopic Examination.—(A) Right lower lobe (six to eighteen hours postoperative): The pleura showed fibrinopurulent pleuritis. The alveoli, bronchioles, and many bronchi were filled with edema fluid, packed erythrocytes, or inflammatory exudate (Fig. 3). The veins, venules, and capillaries were severely engorged. *Microscopic diagnosis:* (1) acute fibrinopurulent pleuritis; (2) pulmonary hemorrhage; (3) pulmonary hyperemia and edema; (4) focal bronchopneumonia.

(B) Right upper lobe (seven days postoperative): The pleura was covered by a thick layer of fibrin containing neutrophiles, nuclear debris, and swollen mesothelial cells, and penetrated at the edge by proliferated capillaries and fibroblasts (Fig. 4). Groups of alveoli beneath the pleura were surrounded and filled by proliferated fibroblasts. In several areas deeper alveoli and alveolar ducts showed loss of the outlines of their walls and were packed with edema fluid and erythrocytes, some including segmented neutrophiles and nuclear debris. Many bronchioles were filled with masses of fibrin enmeshing segmented neutrophiles. The alveolar capillaries and venules were engorged. Some of the larger veins showed thrombosis. *Microscopic diagnosis:* (1) organizing fibrinopurulent pleuritis; (2) pulmonary

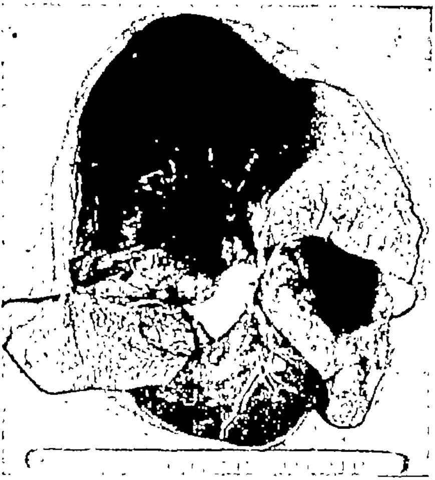

Fig. 1.—Photograph of heart and lungs of dog sacrificed three days following ligation of the pulmonary veins to the right upper lobe.

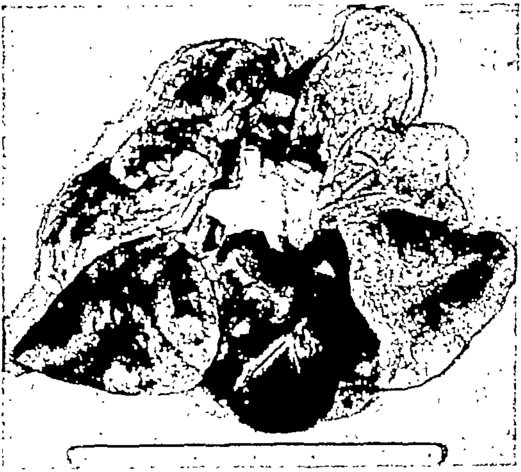

Fig. 2.—Photograph of heart and lungs of dog sacrificed 134 days following ligation of pulmonary veins to right upper lobe.

hemorrhage (with small scattered infarcts); (3) thrombosis of pulmonary veins; (4) organizing pneumonia.

DOG NUMBER V-2.—A black and white shaggy-haired dog weighing 21 kg.

June 2, 1946. Dog given 25 mg. dicoumarin.

June 3, 1946. Dog given 15 mg. dicoumarin. Prothrombin time, twenty seconds (normal). Operation. Ligation of pulmonary veins to right upper lobe.

June 4, 1946. Dog seems quite ill and weak, with severe cough producing blood-stained sputum.

June 5, 1946. Dog found dead.

Autopsy.—Right upper lobe was a deep greyish red and appeared solidified. Middle and lower lobes appeared atelectatic. Left lung normal.

Microscopic Examination.—The right upper lobe (two days postoperative) showed the pleura lightly covered with fibrinopurulent exudate. Many alveoli, ducts, bronchioles, and bronchi were crammed with erythrocytes. Some peripheral alveoli contained edema fluid; others were cystic and empty. The alveolar capillaries, venules, and veins were engorged. *Microscopic diagnosis:* (1) acute fibrinopurulent pleuritis; (2) pulmonary hemorrhage; (3) pulmonary hyperemia and edema; (4) bronchiolectasis.

DOG NUMBER V-3.—A large German shepherd dog weighing 30 kg.

June 6, 1946. Operation. Ligation of pulmonary veins to right upper lobe. Middle lobe vein used for an anastomosis.

June 7, 1946. Dog appears in good condition. Breathing is easy. Moderate cough.

June 8, 1946. Dog died at 8:30 A.M.

Autopsy.—The right chest cavity was filled with blood. The source of the bleeding was not determined. Anastomosis patent. No thrombosis. Upper lobe hemorrhagic and solidified. Middle lobe reddened and slightly shrunken. Left lung normal.

Microscopic Examination.—The right upper lobe (two days postoperative) showed changes almost identical with those described in dog V-2. *Microscopic diagnosis:* (1) acute fibrinopurulent pleuritis; (2) pulmonary hemorrhage; (3) pulmonary hyperemia and edema; (4) bronchiolitis and bronchitis, acute.

DOG NUMBER V-4.—A slick-haired, black dog weighing 15 kg.

Sept. 15, 1946. Operation. Ligation of veins to right upper lobe.

Sept. 17, 1946. Dog doing well. Mild cough.

Sept. 21, 1946. Dog fully recovered; asymptomatic.

Oct. 7, 1946. Dog in excellent health. Sacrificed.

Autopsy.—Wound well healed. Pleural cavities clean. Moderate firm adhesions of right upper lobe to parietal pleura and to mediastinum. Right upper lobe was shrunken, pale, and felt thickened and relatively airless. Other lobes normal.

Microscopic Examination.—Right upper lobe (twenty-three days postoperative). The pleura was thickened with connective tissue poor in elastic fibrils and containing new-formed capillaries. A few small groups of alveoli were collapsed. In many areas proliferated fibrous connective tissue and new capillaries were mingled with macrophages (containing brown pigment granules positive for iron) and lymphocytes. This tissue either filled alveoli and bronchioles, or surrounded and entrapped these structures. The larger veins showed organizing thrombi. *Microscopic diagnosis:* (1) fibrous pleuritis; (2) organizing pneumonitis with interstitial fibrosis and hemosiderosis; (3) thrombosis and recanalization of veins.

DOG NUMBER V-5.—A small, gray-black, long-haired dog weighing 14 kg.

Sept. 13, 1946. Operation. Ligated pulmonary veins to right upper lobe.

September 14, 1946. Dog making uneventful recovery.

October 7, 1946. Dog in good health. Sacrificed.

Autopsy.—Small superficial wound infection lower end incision. Pleural cavities clean. Adhesions between upper lobe and the wound. Right upper lobe slightly reddened and firm. Other lobes normal.

Microscopic Examination.—Right upper lobe (twenty-four days postoperative). The pleura showed thickening, with masses of neutrophiles, macrophages, and lymphocytes mingled

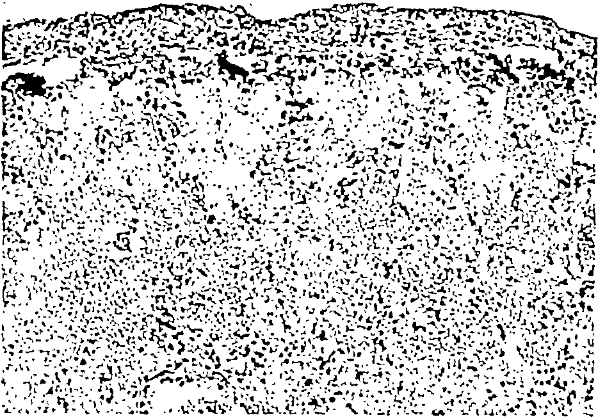

Fig. 3.—Dog V-1. Twelve hours. Fibrinopurulent exudate on pleura. Alveoli and alveolar ducts engorged and hemorrhagic. Hematoxylin and eosin stain. (×150.)

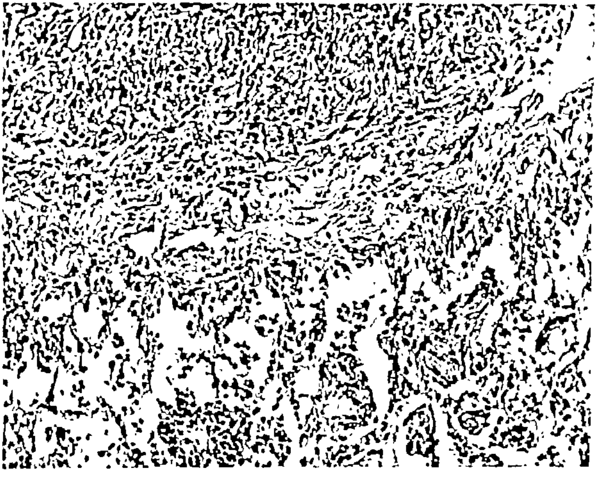

Fig. 4.—Dog V-1. Seven days. Granulation tissue and thickened pleura at top. Alveoli inclosing inflammatory cells and proliferated fibroblasts. Hematoxylin and eosin stain. (×150.)

with proliferated fibroblasts and capillaries, as well as new fibrous tissue poor in elastic fibrils. Alveoli, alveolar ducts, and bronchioles showed widespread collapse. The more superficial ones contained proliferated fibroblasts intermingled with leucocytes. Venules and capillaries were mildly engorged. Macrophages were present, containing iron-positive pigment. *Microscopic diagnosis:* (1) chronic pleuritis; (2) atelectasis; (3) organizing pneumonitis with focal hemosiderosis.

DOG NUMBER V-6.—A German shepherd dog weighing 18 kg.

Sept. 3, 1946. Operation. Ligation of the pulmonary veins to the upper right lobe.

Sept. 9, 1946. Dog has made excellent recovery.

Oct. 7, 1946. Dog in good health. Sacrificed.

Autopsy.—Wound well healed. Pleural cavities normal. Very thick adhesions between upper lobe and the chest wall and mediastinum. Upper lobe appeared whitish, was shrunken, and felt firmer than normal, but not solid.

Microscopic Examination.—Right upper lobe (thirty-four days postoperative) (Fig. 5). The pleura showed thick fibrous connective tissue poor in elastic fibrils and inclosing new capillaries and venules. Much fibrous connective tissue was proliferated in the stroma, thus obliterating or entrapping alveoli, alveolar ducts, and bronchioles. Many hemosiderin macrophages were intermingled in this tissue and were free in a few alveoli. Organizing thrombosis of larger veins was present. *Microscopic diagnosis:* (1) fibrous (''vascular) pleuritis; (2) interstitial fibrosis and hemosiderosis; (3) thrombosis of pulmonary veins.

DOG NUMBER V-7.—A brown collie bitch weighing 17 kg.

Aug. 30, 1946. Operation. Ligation of pulmonary veins to right upper lobe.

Sept. 4, 1946. Dog has had slight cough.

Sept. 10, 1946. Dog seems entirely well.

Oct. 7, 1946. Dog has remained in good health. Sacrificed.

Autopsy.—Wound was well healed. Pleural cavities clean. Many firm adhesions between chest wall and upper lobe. Right upper lobe was pale, moderately shrunken, and felt relatively airless. Other lobes were normal.

Microscopic Examination.—Right upper lobe (thirty-eight days postoperative). Similar to dog number V-6. *Microscopic diagnosis:* (1) fibrous (''vascular'') pleuritis; (2) interstitial fibrosis and hemosiderosis; (3) thrombosis of pulmonary veins.

DOG NUMBER V-8.—A light brown chow dog weighing 26 kg.

May 27, 1946. Operation. An end-to-end venous anastomosis made using right upper lobe vein. The distal end of this vein ligated.

May 29, 1946. Dog in good condition. Has not developed cough.

July 2, 1946. Operation. Right chest opened in order to perform a second and unrelated experimental procedure. There were dense adhesions surrounding the upper lobe. The lobe was dark in color and seemed partially solidified. A generous biopsy of the right upper lobe was taken for examination.

Microscopic Examination.—Right upper lobe (forty-five days postoperative). The pleura was greatly thickened by a vascular fibrous connective tissue poor in elastic fibrils. Many alveoli, alveolar ducts, and bronchioles were collapsed; very few were filled with erythrocytes and edema fluid. Many macrophages (Fig. 6) containing iron-positive pigment were seen. The larger veins showed organized thrombosis. *Microscopic diagnosis:* (1) fibrous pleuritis; (2) atelectasis; (3) focal hemorrhagic edema and hemosiderosis; (4) thrombosis and recanalization of pulmonary veins.

DOG NUMBER V-9.—A short-haired, black and white dog weighing 17 kg.

Aug. 15, 1946.—Operation. An end-to-end anastomosis using right upper lobe vein. Pulmonary end of vein ligated.

Aug. 20, 1946. Dog making uneventful recovery.

Oct. 25, 1946. Dog has remained healthy. Sacrificed.

Autopsy.—Wound well healed. Pleural cavities clean except for adhesions between right upper lobe and the chest wall. Right upper lobe pale, slightly firm. Other lobes normal.

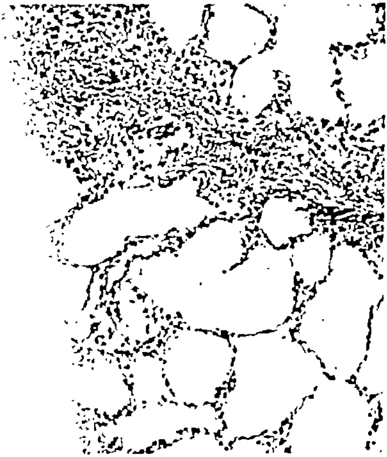

Fig. 5.—Dog V- days. Band of interstitial fibrosis at top. Re- ematoxylin and eosin stain. (×150.)

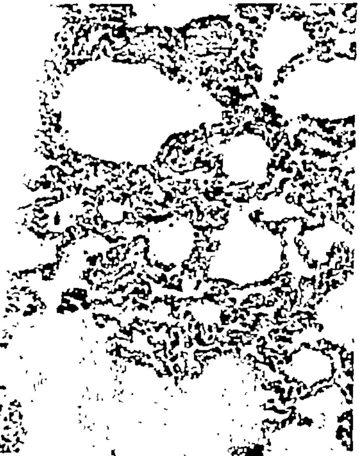

Fig. 6.— V4, irty-f lung for comparison ematc

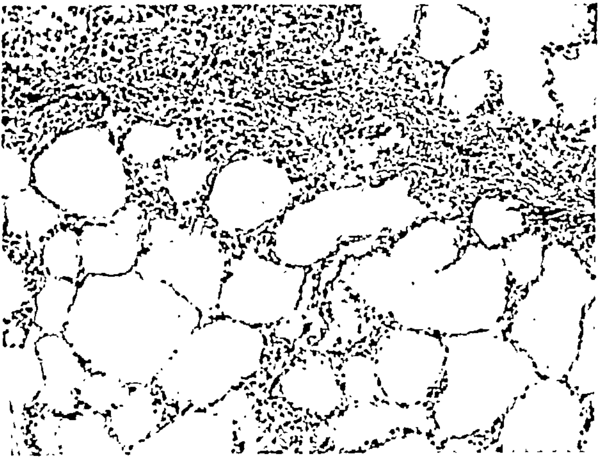

Fig. 9.—Dog V-11. One hundred thirty-four days. Band of interstitial fibrosis at top. Re-expanded alveoli in lower half. Hematoxylin and eosin stain. (×150.)

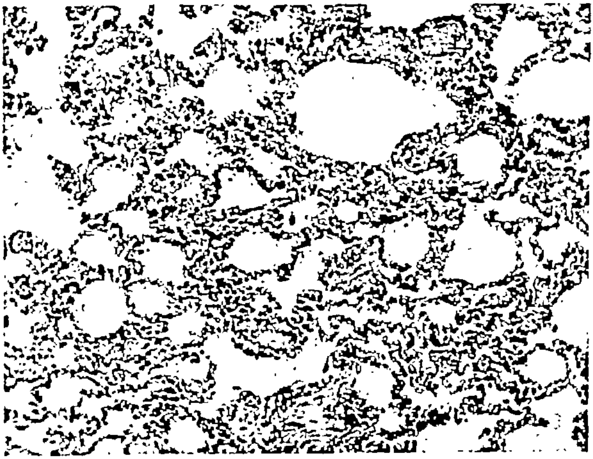

Fig. 10.—Dog V-11. One hundred thirty-four days. Normal lobe of left lung for comparison with Fig. 7. Hematoxylin and eosin stain. (×150.)

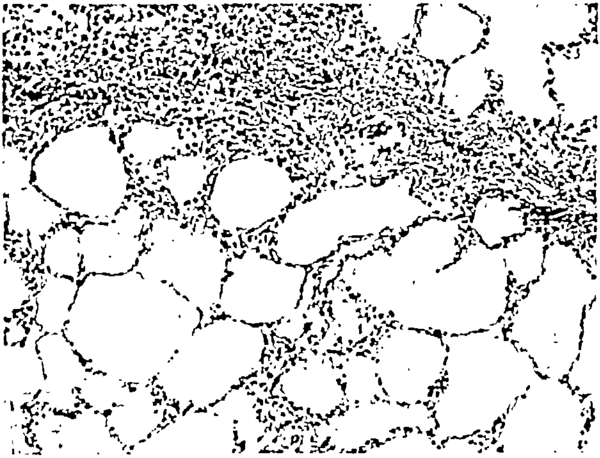

Fig. 9.—Dog V-11. One hundred thirty-four days. Band of interstitial fibrosis at top. Re-expanded alveoli in lower half. Hematoxylin and eosin stain. (×150.)

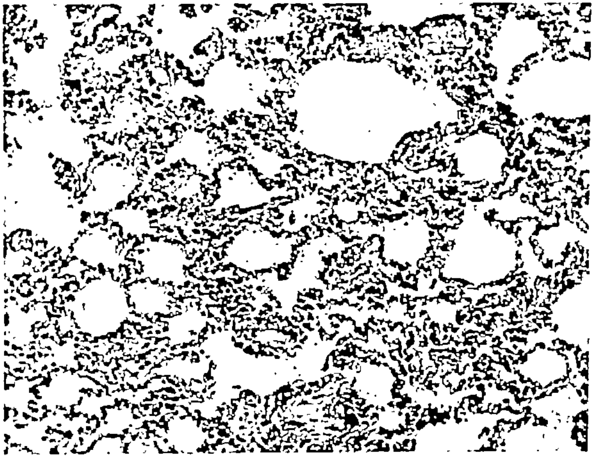

Fig. 10.—Dog V-11. One hundred thirty-four days. Normal lobe of left lung for comparison with Fig. 7. Hematoxylin and eosin stain. (×150.)

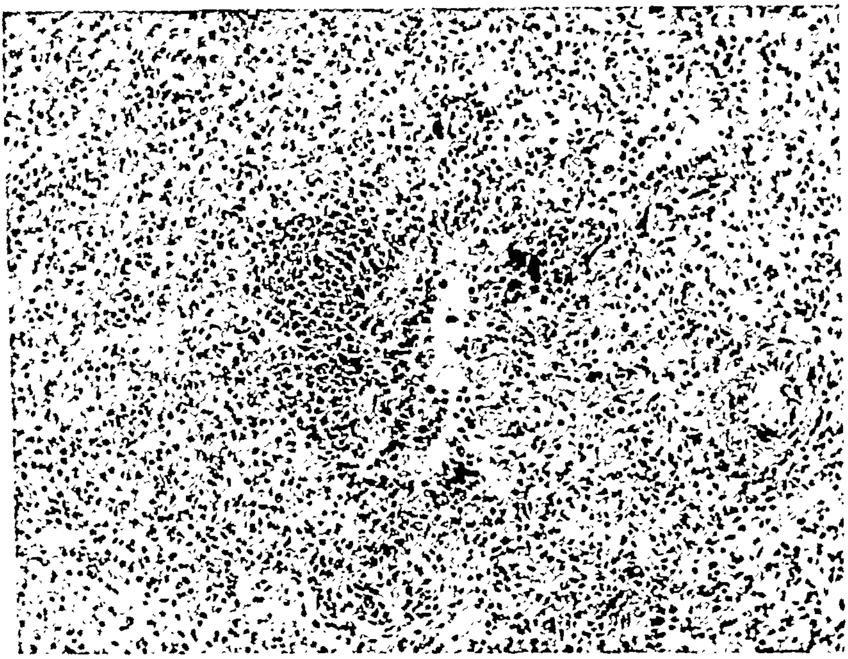

Fig. 7.—Dog V-9. Seventy-one days. Bronchiole at center surrounded by collapsed alveolar ducts and alveoli. Hematoxylin and eosin stain. (×150.)

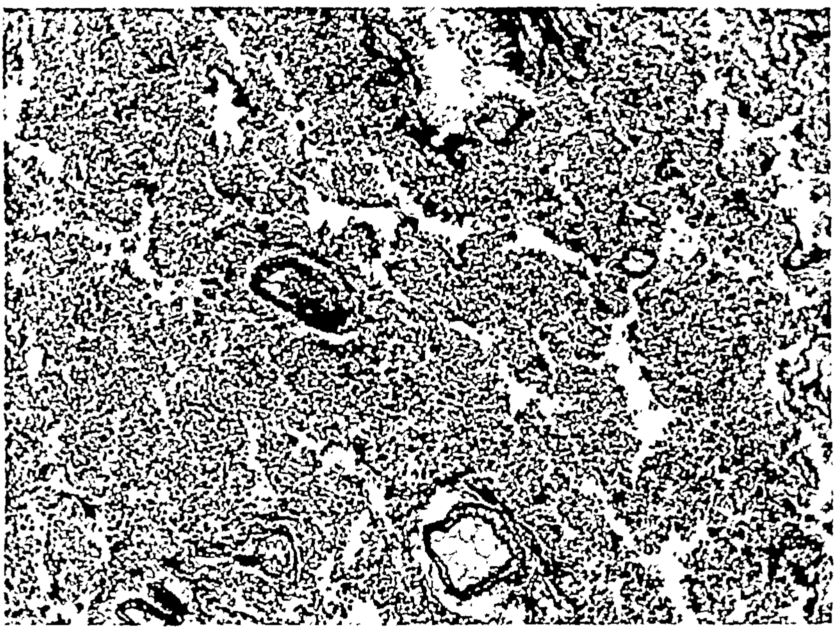

Fig. 8.—Dog V-9. Seventy-one days. Atelectasis. Weigert's elastic tissue stain. (×150.)

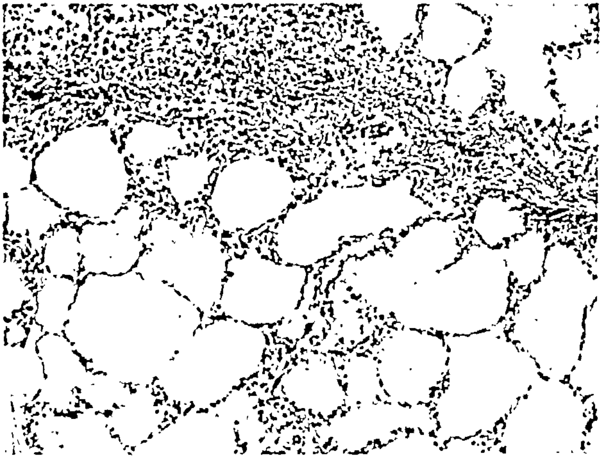

Fig. 9.—Dog V-11. One hundred thirty-four days. Band of interstitial fibrosis at top. Reexpanded alveoli in lower half. Hematoxylin and eosin stain. (×150.)

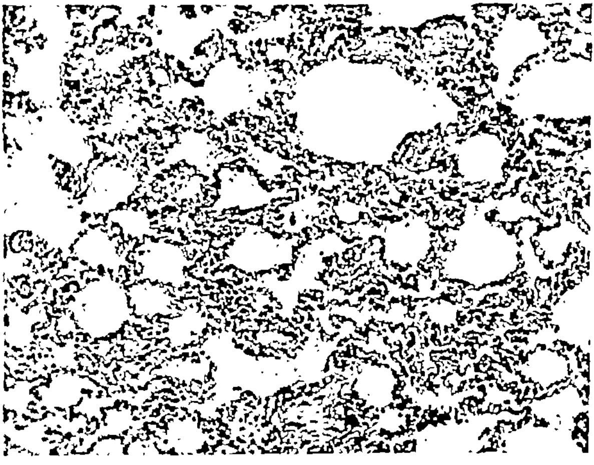

Fig. 10.—Dog V-11. One hundred thirty-four days. Normal lobe of left lung for comparison with Fig. 7. Hematoxylin and eosin stain. (×150.)

Microscopic Examination.—Right upper lobe (seventy-one days postoperative) (Figs. 7 and 8). The pleura was thickened with a chronic suppurative fibrotic reaction. Many alveoli, alveolar ducts, and bronchioles, were collapsed; others were surrounded by strands of proliferated fibrous tissue. *Microscopic diagnosis:* (1) chronic suppurative fibrous pleuritis; (2) atelectasis; (3) focal interstitial fibrosis.

DOG NUMBER V-10.—A tan collie dog weighing 20 kg.

Aug. 12, 1946. Operation. Ligation of pulmonary veins to right upper lobe.

Aug. 15, 1946. Dog has mild productive cough.

Dec. 2, 1946. Dog has remained in excellent health. Sacrificed.

Autopsy.—Wound well healed. Upper right lobe was adherent to chest wall and to mediastinum with fine adhesions, which were dense only in the region of the chest incision. The right upper lobe appeared slightly shrunken, but was almost normal in color, soft to touch, and crepitant. Other lobes were normal.

Microscopic Examination: Right upper lobe (111 days postoperative). The pleura was thickened with vascular fibrous tissue. Many alveoli, alveolar ducts, were well expanded. In several areas thin strands of fibrous connective tissue infiltrated with lymphocytes and iron-positive pigment-laden macrophages, were proliferated around alveoli, alveolar ducts, bronchioles, and in the septa. The large veins showed recanalizing thrombosis. *Microscopic diagnosis:* (1) fibrous pleuritis; (2) interstitial fibrosis and hemosiderosis; (3) thrombosis and recanalization of pulmonary veins.

DOG NUMBER V-11.—A large, black dog weighing 26 kg.

July 30, 1946. Operation. Ligation of pulmonary veins to right upper lobe.

July 31, 1946. Dog has cough productive of blood-tinged sputum.

Aug. 5, 1946. Dog recovered from operation. Cough disappeared.

Dec. 2, 1946. Dog has remained in good health. Sacrificed.

Autopsy.—Wound firmly healed. Right upper lobe adherent to chest wall with breakable adhesions. The lobe appeared normal in size, shape, color, and consistency. Other lobes normal.

Microscopic Examination.—Right upper lobe (134 days postoperative) (Figs. 9 and 10). The pleura was thickened with vascular connective tissue poor in elastic fibrils. Occasional iron-positive pigment-laden macrophages were seen. Strands of fibrous connective tissue extended between some alveoli and in the septa, but most of the alveoli were normally patent. It was estimated that the lobe was 80 per cent aerated. *Microscopic diagnosis:* (1) fibrous pleuritis; (2) interstitial fibrosis and hemosiderosis; (3) thrombosis and recanalization of pulmonary veins.

II. ENTIRE LUNG LIGATIONS

DOG NUMBER L-1.—A small, slick-haired bitch weighing 12 kg.

Sept. 25, 1946. Operation. The left pulmonary vein to the entire left lung was ligated.

Sept. 26, 1946. Animal died at twenty-four hours following operation. She showed extreme weakness, pallor of the mucous membranes, dyspnea, and cough productive of bloody sputum. She presented the picture of progressive shock.

Autopsy.—Pleural cavity on left contained blood-stained fluid. The entire left lung was dark red, completely solidified, and gave the appearance of liver.

Microscopic Examination.—(One day postoperative.) The appearance in all of the left lobes was similar to that seen in the right lower lobe of dog V-1. *Microscopic diagnosis:* (1) acute fibrinous pleuritis; (2) pulmonary hemorrhage, pulmonary hyperemia, and edema; (3) bronchopneumonia; (4) thrombosis of pulmonary veins.

DOG NUMBER L-2.—A brown, long-haired bitch of collie extraction, weighing 11 kg.

Sept. 26, 1946. Operation. Ligation of the entire pulmonary venous return from the right lung.

Sept. 27, 1946. Animal is very weak and is coughing up blood.

Sept. 29, 1946. Animal died three days following operation, and became progressively weaker with increasing pallor.

Autopsy.—The entire right lung is a dark red color, completely solidified, and quite heavy.

Microscopic Examination.—The right lung (3 days post-operative).

Microscopic diagnosis.—(1) Acute fibrinous pleuritis; (2) pulmonary hemorrhage, pulmonary hyperemia, and edema; (3) bronchopneumonia; (4) thrombosis of pulmonary veins.

COMMENT

These experiments indicate that healthy dogs may have the veins from the right upper lobe ligated and divided and survive the operation, probably indefinitely. Of the three deaths in this series occurring following operation, two were the result of an additional but unrelated experimental procedure (dogs V-1 and V-3), and one (V-2) was in an animal under the effect of dicoumarin. We have never had an animal survive a major operative procedure while under the effect of this drug. Eight dogs survived from 23 to 134 days, and were then sacrificed.

On the other hand, ligation of the entire venous return from a lung was fatal within three days in two animals (L-1, L-2). These animals appeared to die of blood loss and shock. The pathologic findings in these lungs were identical with those seen in the single lobe following venous ligation. The difference between survival and death, therefore, would appear to be quantitative, and is related, we think, to the volume of blood loss as pulmonary hemorrhage.

The sequence of events following ligation and division of the veins of one lobe of a lung may be briefly sketched. The first reactions in the lobe include a fibrinous or fibrinopurulent pleuritis with adhesions of the lobe to the parietal pleura. The lobe is pumped full of blood by the intact arteries to it. Consequently, severe hyperemia, hemorrhage, and edema are noted, especially involving the aveoli, alveolar ducts, and bronchioles. Along with the reduced vitality of the pulmonary parenchyma, bronchopneumonia becomes an accompanying reaction. As a result of their ligation, thrombosis occurs in the veins to the lobe.

The process of recovery from these acute changes includes the establishment of adhesions between the visceral and parietal pleura through organization of the acute pleuritis and the formation of new blood vessels, including capillaries, venules, and arterioles to furnish a collateral blood supply, especially venous. Along with this reaction, blood monocytes coming into the arteries migrate from the alveolar capillaries into the alveoli and alveolar ducts and pick up cell debris, especially broken down erythrocytes and the degradation products of hemoglobin, so well demonstrated by the abundant hemosiderin in numerous macrophages, mainly in alveoli, alveolar ducts, and bronchioles early and chiefly in interstitial fibrous connective tissue later. Granulation tissue grows out into alveoli, alveolar ducts, and bronchioles to organize contained exudate. In addition, air is evidently resorbed from some alveoli and alveolar ducts. Widespread atelectasis results from the emptying of the content of these structures by both the scavenging of the hemorrhagic and inflammatory debris and the resorption of edema fluid and residual air. As the collateral blood supply established by the pleural adhesions becomes more abundant in the later stages, especially as seen in dogs V-8 and V-10, the still intact arterial blood vessels are able to vascularize the lobe, especially the alveolar capillaries, and the still intact bronchial tree is able to admit air for the re-expansion of the lobe. The atelectatic areas then largely disappear, the re-expansion beginning first at the periphery of the lobe and then extending centrally. The granulation tissue within the alveoli, alveolar ducts, and bronchioles is either resorbed or incorporated into the interstitial fibrous connective tissue.

The final result after three or four months is a lobe at least 80 per cent re-expanded and apparently functioning with residual vascularized pleural adhesions and focal interstitial fibrosis and hemosiderosis. The thrombi in the proximal ends of the severed veins to the lobe become organized and the veins are recanalized to different degrees.

SUMMARY

1. The pathologic changes in the right upper lobe of the lungs of eleven healthy dogs observed at increasing intervals following ligation and division of the pulmonary veins to that lobe are described.

2. Healthy dogs may survive indefinitely following ligation of the veins to a single lobe, but ligation of the veins to the entire lung in two animals was fatal.

3. There is no significant death of pulmonary tissue following venous ligation. The primary reaction is severe pulmonary engorgement and hemorrhage. Gradually, in a period of about four months, this hemorrhage is resolved, the accompanying intraluminal and interstitial fibrous reaction is absorbed, and with the development of collateral venous channels through adhesions, the lung returns toward normal, approaching full functional activity.

The authors wish to express their appreciation of the excellent technical assistance of Dr. Charles Monroe.

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BRONCHIECTASIS IN SERVICE PERSONNEL

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THIS is a report of the surgical treatment of bronchiectasis undertaken at Christie Street Hospital, Toronto, from 1941 to 1945, inclusive. Christie Street is the local hospital under the Department of Veterans Affairs. Throughout the war years, many men of all services were treated here, both during and after discharge. The surgical treatment was carried on under the supervision of Dr. Norman Shenstone, while the investigation was the responsibility of the Chest Clinic, of which Dr. George Anglin was the chief physician.

There were in this group seventy-five patients, on whom eighty lobectomies were performed. On the whole, these were young men who had been in good physical condition fairly recently. The ages varied from 18 to 47; and averaged 24, with well over half younger than 25 years. The service in which they had enlisted did not seem to have any bearing on the disease, though thirty were in the R.C.A.F., thirty-two in the Army, ten in the Navy, and one was a Nursing Sister.

The site of the disease is of some interest. The left lower lobe was involved in fifty-two cases, and in four of these there was an associated disease of the lingual lobe. The right lower lobe was diseased in thirty-three cases, with an associated middle lobe in seven of them. There were ten with bilateral involvement. Three of these have had complete excision of disease, with a fourth, at the moment, in preparation for the second operation. In two instances, the right middle pobe was found to be involved, and was removed at a second operation.

PAST HISTORY

In reviewing the past histories of these individuals, it is very difficult to be absolutely sure of the presence or the extent of respiratory disease before enlistment. Ostensibly, they were all in good physical condition, with no major respiratory complaint and with an x-ray of the chest declared to be negative at the time of enlistment. In nineteen patients there was a history of definite respiratory infection prior to 1939. This date was taken arbitrarily as being about the time of earliest enlistment in the Canadian Armed Services. This infection varied from a series of severe head colds, to recurrent attacks of pneumonia, to a chronic cough with sputum over a period of years which was a feature in only three cases.

The next group of twenty-two cases showed no history of pneumonia, and no definite major respiratory infection before 1940. However, all had had frequent upper respiratory infections since enlistment, and many had developed cough and sputum following these infections. They were not hospitalized, as a rule, until the time bronchiectasis was diagnosed.

Read (by title) at the Twenty-Sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30, and 31, 1946.

TABLE I

Age	18 to 47; average, 24	
Service		
	R.C.A.F.	30
	Army	32
	Navy	10
	Nursing Sister	1
Site		
	Left lower	52
	Lingual	4
	Right lower	33
	Middle	7
	Bilateral	10

TABLE II.

PAST HISTORY	NO.
Respiratory infection before 1939	19
Frequent upper respiratory infection	22
Pneumonia twice or more	21
Pneumonia once	19

There were another twenty-one patients who gave the usual history of more than one attack of pneumonia, followed by persistent cough and sputum. There were nineteen patients who had no previous major respiratory infection, had had one attack of pneumonia only, since 1940, and had a persisting cough and sputum following this one attack. It is suggested that this is a virus type of pneumonia. This is a very important group, as their history supports the hypothesis that bronchiectasis can and does develop as a relatively acute disease, and is not one necessarily of many years' duration. In reviewing the whole series of seventy-five patients, it is seen that forty-one, or well over half, had had no major respiratory infection prior to enlistment, and had developed bronchiectasis over a brief period of one to four years. On checking more closely, it is found that fourteen of these gave a history of six months or less before admission to hospital and diagnosis of bronchiectasis.

SYMPTOMATOLOGY

At the time of their final admission to hospital for investigation and assessment, all patients complained of cough and sputum. The severity of cough and the amount of sputum varied considerably, but there is no doubt that there were relatively few who had the copious foul-smelling sputum previously associated with bronchiectasis. Other symptoms were absent in the great majority, but there was a history of: hemoptysis in eight, loss of weight in six, loss of strength in nine, shortness of breath in seven, and pain in chest in four.

Physical signs, as usual, were not outstanding, but râles were heard over the affected area in practically all the patients. There were frequent observations of decreased movement and dullness in the involved base. A routine examination of the upper respiratory passages and sinuses was made in each case by the otolaryngologist. It was a distinct surprise to note that the examination was negative in practically every case. Only one patient was diagnosed as having pansinusitis. He also had bilateral bronchiectasis. Routine bronchoscopic examination was also done, and no tumors were found in this series. There was one bronchial stenosis. The great majority showed only purulent discharge from the involved area. Bronchograms were, of course, checked very carefully for localization and extent, with particular attention to the lingula and the right middle lobes.

OPERATION

Preoperative preparation was very much the same in all cases. The patients were on full diet with extras; they had constant postural drainage for varying lengths of time, depending on the amount of sputum. Any foci of infection were cleared up as well as possible. Their blood was typed, and at least two pints of blood obtained for the operation. Anesthesia was intratracheal ether and oxygen, or cyclopropane and oxygen. In all cases the posterolateral incision was made, and in the majority, the patient was placed in the lateral position. In a very few of the more recent cases, the prone position was used, with a great improvement in the aeration of the good side. The diseased sections of the lung were removed by dissection lobectomy in all but one instance, in which there had been chronic pulmonary infection for many years. When feasible, the cut margins of the pleura were sutured over the hilar structures. In thirty-five cases, sulphathiazole powder was dusted in the pleural cavity; and in the last forty-five, penicillin and sulphathiazole powder. A closed intercostal drain was inserted by a stab wound low in the thorax, the ribs approximated with wires, and the intercostal muscles sutured. Oxygen was administered postoperatively for at least twelve hours, and often for twenty-four hours. The foot of the bed was raised for those who had had much sputum or bilateral disease. After eight hours the patients were turned every two hours. The drainage tube was removed after forty-eight hours, and it was rarely necessary to aspirate the chest later. Most of the patients were out of bed in a week, and many more in ten days. The majority were ready to return to the chest clinic for convalescence three weeks after operation. Here the lung expansion was checked carefully and encouraged by supervised breathing exercises. When the patients were ready to leave hospital, they were usually given three months' convalescent leave, reporting to the outpatient clinic regularly during that time.

COMPLICATIONS

The commonest complication postoperatively was empyema, which occurred seven times. In three of these cases, the infection was overcome by aspiration and injection of penicillin, and cleared up quite readily. In the other four, rib resection was done. In one, the wound was healed in two months' time; in the second, in three months' time. They had no further trouble. The third empyema drainage lasted four months, but then healed without further incident. The fourth empyema requiring drainage followed the resection of right middle and lower lobes. In that case, there was no definite separation between upper and middle lobes, and it was done at a time when we were making the separation by clamping, cutting, and oversewing the cut margin. This prevented satisfactory expansion of the upper lobe and the residual cavity became infected two months postoperatively. It is still draining. I believe it is of interest to note that five of these infections occurred in the period when we were using sulphathiazole alone, and only two when we used penicillin and sulphathiazole.

Bronchopleural fistula occurred only once in this series. This man had had a long history of chronic pulmonary disease and it was thought advisable to use the lung tourniquet in removing his right lower lobe. He developed an empyema one week after the operation. This was being treated by aspiration and injection of penicillin when, a week later, he demonstrated a bronchopleural fistula by coughing up the suppuration. Fortunately, he was able to keep the cavity empty by postural drainage and it gradually diminished in size by expansion of the adjacent lung. It was never thought necessary to drain the empyema externally. His chest eventually cleared up completely. He reported recently as being in fair health, with some residual cough and sputum, but working full time at a light job.

The only other complications were pneumonia in two cases, and thrombophlebitis in one case. One of the pneumonia cases was considered to be a lipoid pneumonia, due to lipiodol retained in the good lung. The other occurred in the only patient who was diagnosed as having a pansinusitis preoperatively. This may have had some effect on his postoperative course. Both of these were out of hospital within two months. There seemed no special reason for the development of the thrombophlebitis. It had completely disappeared when the patient was examined in clinic three months postoperatively, with no further complications.

MORTALITY

There was one death in this group of eighty operations. This young man of 20 years had had chronic cough with sputum for twelve years. He had a history of very frequent colds, but in spite of this he enlisted in the R. C. A. F. in October, 1943. He went overseas in June, 1944, but because of frequent respiratory infections, he was repatriated in May, 1945, and admitted to Christie Street Hospital in June. Investigation there showed bilateral bronchiectasis, definitely more marked in the right middle and lower lobes. He was treated in the chest clinic for three months, when he was advised to have right middle and lower lobectomy. This was started on September 11, but the anesthetist had very early difficulties with large amounts of tenacious mucopurulent discharge, hence, the operation was stopped before the chest was opened. He was referred back to the chest clinic, and every effort was made to clear out the bronchial tree. It was considered that definite progress was made, and about three months later a second attempt was initiated. Bronchoscopic suction was employed immediately before the operation and the anesthetist made every effort to keep the airway open. There was not quite so much discharge on this occasion, although there was never a perfectly clear aeration. Toward the end of the dissection of the hilum, more respiratory difficulty was encountered, and the patient died on the table. Autopsy showed plugging of the opposite bronchus with mucopus, and almost complete pulmonary collapse. Since that time we have used the prone position in preference to the lateral, and think that these respiratory difficulties are lessened, although not eliminated.

FOLLOW UP

Recent information on these patients was obtained in various ways. The majority were circularized by questionnaire; others were seen on recall to the outpatient clinic, while others, the most recent, were still attending the clinic. In all, out of a total of seventy-four, fifty-eight patients were contacted; three of these were in hospital; two were waiting further surgical procedures; one was recovering from a severe respiratory infection; and twelve had been operated on within the last three months of 1945, and were still attending clinic. There were forty-seven replies to the questionnaire. It was quite obvious that they did not magnify their good health. Possibly due to the pension angle, there was more pessimism displayed than was warranted by a check examination on a few of them. There were, in addition, five who had returned to clinic during 1945, and who reported themselves as well, free of cough, and sputum, and working full time.

In summarizing the results in fifty-two patients, their general health was reported to be, good in sixteen, fair in thirty-one, and poor in five. Of those in poor health: one had hemoptysis recurring from a small residual area of bronchiectasis; one had had a bilaterial involvement with removal of one lower lobe only; one had empyema and a nonexpanded right upper lobe (referred to under complications); one had several acute respiratory infections and was in hospital at the time; one had a small amount of intercostal neuritis. He was seen in clinic in January, 1946. He was in good health.

With regard to cough and sputum, nine reported no cough; twelve reported no sputum; twenty reported slight cough and sputum; twenty reported an appreciable amount of both cough and sputum.

Of those having definite cough and sputum, the majority reported a marked lessening following operation, with a few unchanged.

Activity.—Twenty-one of the fifty-two patients reported as doing full-time work; eleven of the fifty-two patients reported as doing part time work; thirteen of the fifty-two patients reported as doing no work at all. The majority of these thirteen had been operated on during the last six months, while another three of them were in hospital, two waiting further surgical treatment. Seven patients were at school.

SUMMARY

1. A series of eighty lobectomies for bronchiectasis is reviewed as to: site, previous history, present history and findings, preoperative preparation, and operative technique.

2. Complications were few, and were as follows: empyema, seven; bronchopleural fistula, one; pneumonia, two; thrombophlebitis, one.

3. There was one death; a mortality of 1.25 per cent.

4. Follow-up reports in fifty cases showed: good or fair general health, 90 per cent; slight cough and sputum or none, in 60 per cent; working full or part time or at school, in 74 per cent.

PNEUMOPYOPERICARDIUM

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PNEUMOPERICARDIUM is a rare condition. It is still more uncommon if this pneumopericardium becomes infected. The condition then turns into pneumopyopericardium. The outlook, once the diagnosis is made, is exceedingly grave. Patients with cases of traumatic origin are more likely to recover. In the majority of instances pneumopyopericardium is a terminal complication of a serious disease, and then the result is usually fatal.

HISTORICAL

Galen is said to have removed a portion of the sternum and anterior wall of the pericardium in a soldier with a neglected chest wound. Surgical intervention is said to have cured the suppurative pericarditis. (Quoted by Winslow and Shipley.) Romero, in 1819, drained a serous pericarditis between the fifth and sixth ribs. Larrey, ten years later, in a stab wound of a soldier, suggested the xiphocostal approach to the pericardium. Laennec, in his writings, mentioned the value of the tympanitic sound at the superior portion of the heart to denote the presence of air in the pericardium. However, such eminent diagnosticians as Skoda, the discoverer of percussion and auscultation, and Schroetter (1898) his successor at the Vienna City Hospital, never saw a case of pneumopericardium in well over thirty-five years of experience. Bricheteau observed hemopneumopericardium in 1844 and in the same year Hilsmann reported curing a patient with pyopericardium. von Langenbeck (1860) performed pericardiotomy successfully, and Stokes collected three reported cases in 1855. Rosenstein in 1881 established surgical intervention as the method of choice in treating suppurative pericarditis. In 1885 Malle evacuated a hemopericardium through an opening made in the sternum and Bexman in 1891 performed the same procedure for a pyopericardium. James in 1904 reported on thirty-seven cases of pneumopericardium and mentioned the rarity of the disease. Rosler in 1918 collected seventy-three similar cases. Harvey B. Stone reported on a case of pericardiotomy for suppurative pericarditis following pneumonia performed on June 27, 1918, in Field Hospital No. 327 in France. More recently Winslow and Shipley (1935) reported on 118 patients with suppurative pericarditis of which twelve cases were due to gunshot and stab wounds. The remaining 106 cases were due to systemic infection. Winslow and Shipley operated upon 4 patients. Two of these recovered and two died.

ETIOLOGY

The causes of pneumopericardium and its complicating pneumopyopericardium may be divided into three main headings: (1) trauma, (2) perfora-

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Read (by title) at the Twenty-Sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30, and 31, 1946.

tion from neighboring organs, and (3) infection, or the spontaneous development of fluid, pus, and gas in the pericardium.

In taking up these three subdivisions separately one finds:

1. Trauma.
    - A. From without:
        - a. Punctured wounds, gunshot, and knife wounds. (Mueller, Thompson and Walsh, Bodenheimer)
    - B. From within:
        - a. Perforation of the esophagus into the pericardium by
            - 1. Swallowed knife or denture. (Thompson and Walsh, James and Imperatori)
            - 2. Swallowing of long strips of wire and metal. This is common in cattle and rare in man.
    - C. Fractured rib or sternum tearing the pericardium.
    - D. Spontaneous rupture of the bronchus into the pericardium by violent vomiting (Dufour and Barouk) or by strenuous bodily exercise and exertion (Ljungdahl) and by blast injury.
    - E. Artificial
        - a. Accidental
            - 1. Tuberculous pericardium mistaken for a tuberculous pleurisy and a pneumopericardium instead of a pneumothorax was induced (Rigler, Saupe)
            - 2. A hemopericardium was aspirated and air had been allowed to enter at time of pericardicentesis. A contaminated hemopneumopericardium resulted which grew *Staphylococcus aureus* on culture. (Harken, personal communication. Case seen during army service.)
        - b. Intentional. Aspiration of pericarditis with effusion and replacement with air. (Oppenheimer)
2. Perforation of inflammatory or suppurative foci into the pericardium from neighboring organs and structures, and vice versa.
    - A. Tuberculosis.
        - a. Lung cavity into the pericardium. (Laub, Langer, Poirier)
        - b. Caseous tuberculous lymph node behind the bifurcation of the trachea becoming adherent to the esophagus. This caused a traction diverticulum of the esophagus which broke through, causing a sinus from the esophagus through the lymph node into the pericardium. Two somewhat similar cases are reported. (Leys and Wallace, Zwilling)
        - c. Tuberculous lymph node breaking into the pericardium and then into a bronchus or the lung. Four such cases are reported by James.
    - B. Infection and suppuration.
        - a. Perforation of an empyema cavity which had been surgically drained, into the pericardium; and the perforation of a lung abscess or lung gangrene into the pericardium. (Jobin)

  - b. Perforation of pyopneumothorax into the pericardium. (Eisenlohr, Sievers)
  - c. Perforation of a liver abscess into the subdiaphragmatic space then into the stomach and finally into the pericardium. (Graves quoted by Müller)
  - d. Mediastino-pericarditis perforation. (Mayer)
  - e. Perforation of peptic ulcers into the pericardium. (Salmony, Saexinger, Moizard, Parisot)

3. Systemic infection causing suppurative pericarditis.
   - A. Secondary to pneumonia, pleurisy, and Ludwig's angina.
   - B. Spontaneous development of gas in the pericardium due to infection is extremely rare but is reported. *Bacillus welchii rarely* leads to a pneumopyopericardium. Ringler reported five cases of which one recovered. Harken saw a case of pneumopyopericardium in the armed service in which the organism was the *B. welchii.* It was penicillin sensitive and the patient recovered after aspiration and penicillin instillation. (Personal communication)
4. Perforation of malignant tumors into the pericardium.
   - A. Gastric carcinoma. (James)
   - B. Esophagus carcinoma. (James, Chambers, and Tütel)
   - C. Bronchus carcinoma.
5. Perforation of primary suppurative pericarditis.
   - A. Into cavities containing air. (Romberg, MacDovel quoted by Laub)
   - B. Suppurative pericarditis perforating externally. (Müller)

SYMPTOMS

The symptoms of pneumopericardium and pneumopyopericardium, when due to perforation, are the sudden onset of precordial pain. The patients become dyspneic and cyanotic. Frequently they faint. They may also complain of acute upper abdominal pain. Swelling in the precordial region may occur but is rare. Occasionally the patient complains of peculiar sensations and is conscious of peculiar sounds in the region of the heart noticed with each heart beat.

PHYSICAL SIGNS

The area of cardiac dullness suddenly disappears and is replaced by an area of hyperresonance. The percussion note is deep and sonorous and almost tympanitic. The area of tympany may shift with the change in position of the patient.

On inspection, especially in children and young adults, there may be bulging in the heart region. The patients all have fever and a rapid pulse. The pericardium usually is enlarged. There is venous stasis throughout the body, as the heart has difficulty in filling due to compression. The heart itself is usually pushed forward against the chest wall. This must be kept in mind when performing a paracentesis.

On auscultation, very definite and characteristic sounds are heard. A metallic sounding phenomenon is present with a splashing and tinkling sound heard at the apex of the heart synchronous with the heart beat. Patients themselves are frequently conscious of this phenomenon. The sound is that of a gurgling brook or the bursting of bubbles, or the splashing of water on the wheel of a water mill.

DIAGNOSIS

The x-ray films are distinctive and offer the greatest help in diagnosis. The x-ray exposure must be short to give a sharp outline. There often is a double shadow, the inner heart shadow and an outer one, either that of fluid or air or both in the pericardium. (Schulze, Schwaer, Amelung.)

Aspiration of the pericardium is of great diagnostic value. Culture of the aspirated fluid is important. Harken, in a personal communication, has drawn attention to the importance of culture in making a diagnosis. He has seen a patient in whom a diagnostic aspiration of what was believed to be a pericardicentesis for suppurative pericarditis revealed pus which on culture showed mixed organisms. At surgical pericardiotomy a mistake in diagnosis was apparent. An extrapericardial abscess was found that had dissected around the pericardium to an extent that it had been mistaken for a suppurative pericarditis. The x-ray and fluoroscopic appearance was classical. At operation the pericardium was closed and the mediastinal empyema was drained from behind without entering the pleural space. The patient did well. Harken states that the presence of mixed organisms should have made one suspicious of an extrapericardial abscess. A short time later Harken saw a similar case and in this instance injected lipiodol into the pericardial sac. He was thereby able to show that the pericardium was not involved in the abscess.

Pericarditis is frequently overlooked in its insidious onset during a grave disease. Its presence must always be kept in mind and must be ruled out.

In the differential diagnosis one must rule out mediastinal pleuritis, a dilated esophagus, a paravertebral abscess and an aneurysm of the abdominal aorta. All of these conditions may give similar x-ray films.

Pneumomediastinum may be a complication of surgical emphysema, especially in chest wounds, and must also be kept in mind.

OPERATIVE TECHNIQUE

Anesthesia for pericardiotomy may be either local or general. If general anesthesia is chosen the introduction of an intratracheal tube is of value.

A curved incision is made just to the left of the sternum from the level of the second rib downward and then outward onto the left costal arch. The fourth, fifth, and sixth and sometimes the third costal cartilages are resected. The internal mammary vessels are ligated and divided. If necessary, some of the lateral border of the sternum is resected with rongeur. Every effort is made to avoid injury of the pleura. It is wiped away if not too adherent by inflammatory adhesions. The pericardium must be well exposed and free of pleura.

The pericardium is then incised longitudinally in its long axis for good drainage, all the way down to its most dependent portion. The pericardial sac is explored with the finger and adhesions are broken with great gentleness. The pericardial sac is then irrigated gently and 25,000 to 40,000 units of penicillin in about an ounce of saline are instilled. No irritating fluid should be used for irrigation. Beck has shown in the dog that Dakin's solution can cause adhesive pericarditis. If the pericardial sac is irrigated, one should be sure to have free exit for the fluid. The wound is left open and if the suppuration subsides and the wound is granulating, secondary closure of the skin over the heart is performed.

The former trans-sternal and xiphocostal approaches to the pericardium are not as efficient as the technique above described.

Complications.—One must watch for a possible associated empyema and suppuration in neighboring organs. A serious complication and one that must be carefully observed is that of constrictive pericarditis (Pick's Disease). Fortunately, it is not common as a postoperative complication.

PROGNOSIS

The prognosis is always grave. In suppurative pericarditis, 70 per cent cures are possible. In pneumopyopericarditis the outlook is not so good. The chief factors influencing the prognosis are the time of operation, the type of organism involved, and the original condition of which the pyopericardium or pneumopyopericardium is the complication. Also whether there are other foci of suppuration elsewhere in the body.

The immediate and late prognosis is serious. Immediate drainage offers the only hope, with the help of chemotherapy. In the traumatic group of cases the prognosis is somewhat better. In all others it is extremely poor from the very beginning.

Müller reported three cures in pneumopyopericardium. Two were traumatic cases, and one was a perforation of an empyema into the pericardium. The prognosis in pericardiotomy for suppurative pericarditis is much better than in pneumopyopericardium. Winslow and Shipley reported on 118 patients with suppurative pericarditis with ten of their own, making 128 in all. Seventy-one or 55.47 per cent recovered and fifty-six or 43.65 per cent died. In one case the result was not known. Necessarily the prognosis must be modified by the primary disease involved.

CASE REPORT

On March 3, 1945, a Russian Displaced Personnel girl, 23 years of age, was admitted to our evacuation hospital ten days after having been injured by a fragment of a hand grenade.

She was desperately ill and very toxic. There was deep jaundice. The temperature was 102.4° F., pulse 140, blood pressure 110/62. Hematocrit was 17.5 per cent, hemoglobin 6 Gm., total protein 6.5 Gm. White blood cells 53,000 with a high differential count.

She was immediately given blood transfusions. On physical examination the patient was dyspneic, cyanotic, and orthopneic. She was alert and rational. There was a wound of entrance over the third rib just to the left of the sternum and a smaller one in the left breast at about 9 o'clock near the periphery of the breast. From the larger wound, thin,

53385

frothy pus was exuding. The left chest was dull on percussion posteriorly, and on auscultation there was bronchial breathing at both bases. On percussion the heart dullness was increased to the right and to the left and on auscultation over the heart there was a typical bubbling, tinkling, babbling, and swishing sound. The abdomen was distended and tympanitic. The liver was palpable. There was no edema over the sacrum or the lower extremities.

X-ray examination showed a typical pneumopericardium with a foreign body within the pericardium in the region of the great vessels. There was dense infiltration of the left lung field (Figs. 1 and 2).

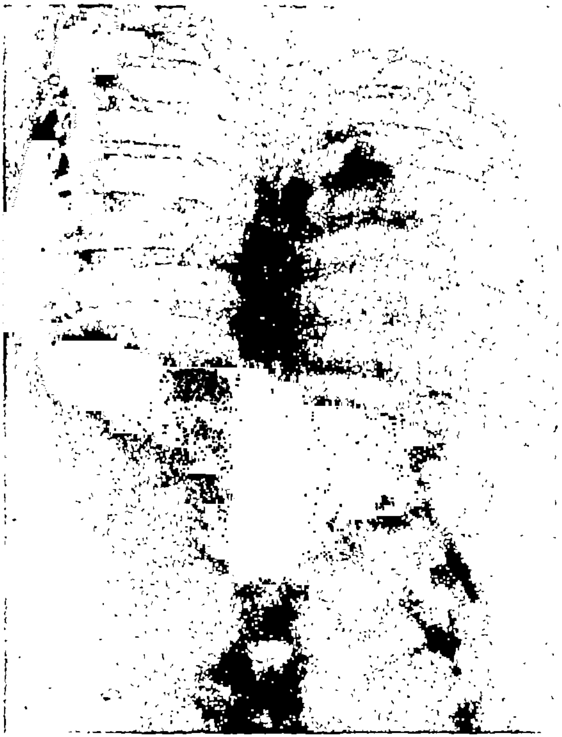


Fig. 1.—X-ray film showing pneumothorax with grenade fragment in pericardium.

After sufficient preparation with infusions and transfusions, pericardiotomy was decided on.

Operation was performed March 4, 1945. GOE endotracheal anesthesia was administered by Lt. Col. Max Frick. The incision was made from the wound of entrance along the left sternal border to the fifth interspace and then curved outward. A skin and muscle flap was dissected outward exposing the ribs and cartilages. The third, fourth, fifth, and sixth rib cartilages, with about an inch of the bony ribs were resected. The intercostal structures were ligated and resected. The internal mammary vessels were ligated, divided, and removed. About three-fourths of an inch of the left border of the sternum was resected with a rongeur forceps. This exposed the pericardium with the wound of entrance in its upper portion. The pericardium was incised from the wound of entrance downward to the most dependent portion. The grenade fragment was lying slightly embedded on the pulmonary artery and was removed. The heart was covered with thick fibrin and bathed in frothy pus. The finger was introduced into the pericardium and behind the heart and many fine, fairly fresh adhesions were broken up. The pericardial sac was irrigated with saline and it was seen that the wall of the pulmonary artery was slightly injured where the missle had lodged. 40,0000 units of penicillin were instilled into the pericardial sac. The skin wound to the left in the breast region was sutured. The remainder of the wound was left open and the parietal pericardium loosely stitched to the endothoracic fascia. The edges of the wound and the heart were covered with petrolatum gauze. The patient stood the surgical procedure nicely. (Fig. 3.)

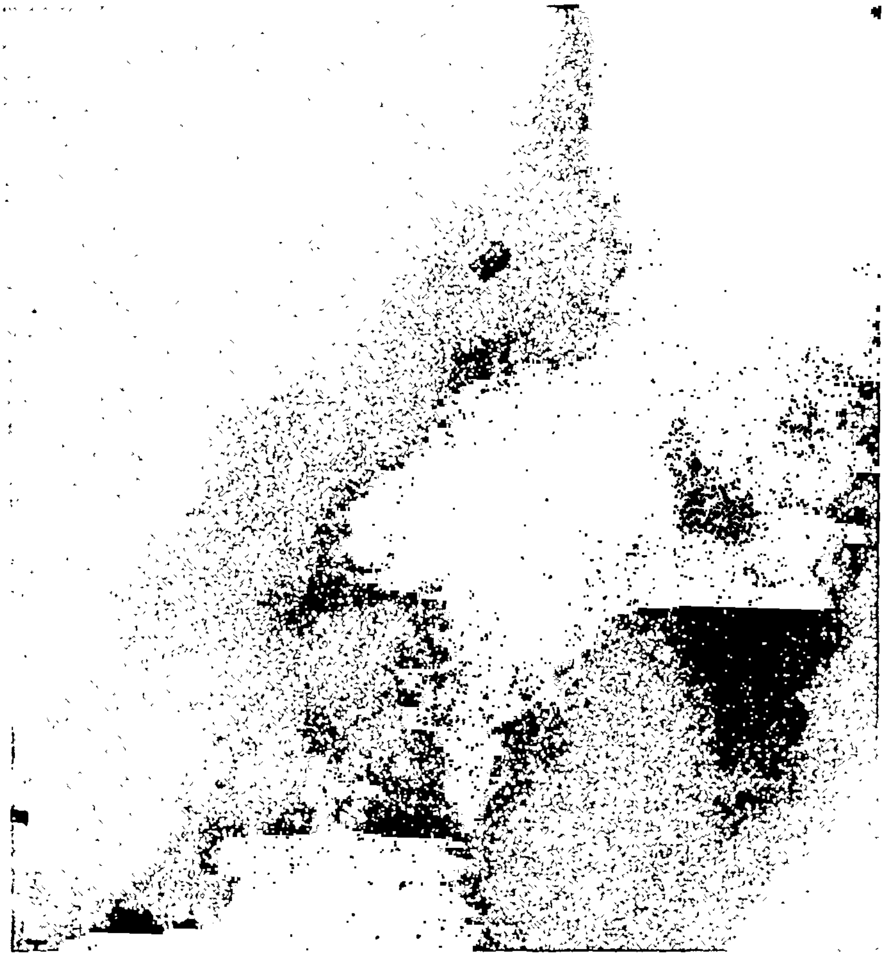
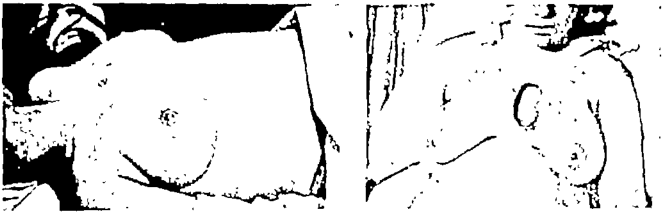


Fig. 2.—Lateral x-ray film showing the same as F'g. 1.

Postoperative Course.—Penicillin, 40,000 units q. 4 hours and sulfadiazine Gm. 1 q. 4 hours, which had been started on admission, were continued. The smear from the pus from the pericardium showed many gram-negative and gram-positive diplococci. The serum bilirubin was 9.0 mg. per cent. The hematocrit reading on day of the operation was 30 per cent, hemoglobin, 10.2 Gm. and protein 5.8 Gm. The day after the operation 125 c.c. of fluid were aspirated from the left pleural cavity in the posterior axillary line. This aspiration was repeated daily and on the third postoperative day 225 c.c. were removed. Each time, 40,000 units of penicillin were instilled into the pleural cavity. Two hundred and fifty cubic centimeters of fresh whole blood in Alsever's solution were given daily for four postoperative days. On the fourth postoperative day there was an allergic reaction and the transfusions were temporarily stopped. Vitamins were given parenterally and per os. At every dressing the finger was passed around the heart and thick fibrin placques were removed. There always seemed to be some retention behind the heart in the pericardial sac. On the fifth postoperative day the patient developed some edema over the sacrum, buttocks and lower extremities. The venous pressure was 160 mm. H_2O. Two days later 2 c.c. salygran was given intravenously after consultation with the medical service. Also 250 c.c. of blood in Alsever's solution. There was again a reaction after the transfusion. A week after the operation the condition of the patient had greatly improved. Still very large amounts of fibrin placques were digitally removed from the pericardial sac. Six days later, or fourteen days after the operation, the patient was improving. There was still evidence of left pleuropulmonary pathology. There was, however, not much evidence of pleural exudate. The kidney output was satisfactory. The pus discharge from the pericardium was getting materially less. The pericardial sac was irrigated daily.



A. B.

Fig. 3.—*A*, patient on operating table showing wound of entrance in precordial region; *B*, patient one week after operation showing wound of pericardiotomy.

Due to the tactical situation, our hospital received orders to advance and the hospital was closed. Through the help of G 5 of the Army, the patient was transferred to another army hospital on the fourteenth day after operation in fairly satisfactory condition.

I was later informed by the Chief of the Surgical Service of the hospital that very shortly after transfer to the hospital the patient developed complete suppression of urine and in spite of everything that was tried she went into uremic coma and died five days later. A post mortem was performed.

The gross anatomical diagnosis of the autopsy was: (1) pericarditis, acute, marked, associated with (a) pyopericardium, (b) myocarditis with moderate right ventricular dilatation, and (c) acute mediastinitis; (2) bilateral hydrothorax; (3) pulmonary atelectasis, partial associated with pulmonary congestion; (4) acute cholecystitis, moderate; (5) pyelonephritis with pus in both pelves; (6) marked cystitis; (7) passive congestion of kidneys, liver and spleen; and (8) bilateral fibrous pleuritis.

SUMMARY

1. Early diagnosis and recognition of pneumopericardium and pneumopyopericardium is of vital importance.
2. The physical signs and x-ray findings are very characteristic.
3. Suppurative pericarditis is too frequently overlooked, as proved by autopsies.
4. The prognosis in suppurative pericarditis is fairly good.

5. Traumatic etiology in pneumopyopericardium holds out a fair prognosis.

6. Pneumopyopericardium as a complication of some other grave disease has an extremely poor prognosis.

7. Early surgical intervention, aided by proper chemotherapy, holds out the only hope of cure.

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MEDICAL TREATMENT OF ACUTE AND CHRONIC PULMONARY ABSCESSES

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INTRODUCTION

MULTIPLE embolic abscesses, abscesses secondary to pulmonary neoplasms and primary bronchiectasis, together with tuberculous and mycotic infections, have been excluded from this study; but cases of acute and chronic suppurative bronchopneumonia and abscesses which precede, accompany, or follow bronchiectasis have been included.

In 1936, Allen and Blackman[2] collected 2,114 cases of pulmonary abscess from the American literature and found that the mortality in patients receiving medical treatment was 34.4 per cent and in those receiving both medical and surgical treatment was 34.2 per cent.

During the past ten years, remarkable progress has been made in the techniques of pulmonary surgery, and one would expect this to be reflected in a material reduction in mortality, yet among 2,166 cases collected from representative clinics since 1936, the gross mortality remains 34.2 per cent. Among 906 patients receiving medical treatment, the mortality was 34.7 per cent, while the mortality among 744 cases treated by surgical procedures was 32.7 per cent (Table I).

Tables II and III show a wide variation in mortality from clinic to clinic for both medical and surgical therapy. Neuhof and Touroff[32, 33] stand alone in reporting entirely satisfactory results with but four deaths in 152 cases, or a mortality of 2.6 per cent. This low mortality was obtained by operating on abscesses of less than six weeks' duration and presumably by excluding from this series abscesses designated by Neuhof and Thomas[31] as "acute suppurative bronchopneumonia."*

Speaking as an internist, it is my impression that the general practitioner and the internist, not the surgeon, are primarily responsible for the conditions which result in the death of one-third of the patients who develop primary pulmonary abscesses. The following analysis of our cases, supplemented by a study of the literature for the past ten years, is presented with the hope that the medical treatment of primary pulmonary abscess can be improved sufficiently to give a final mortality for the combined medical and surgical therapy of less than 10 per cent.

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Read (by title) at the Twenty-Sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30, and 31, 1946.

*The mortality in this type of pulmonary suppuration was 24.2 per cent of 120 cases and was primarily medical rather than postoperative. This type of suppurative pulmonary disease has been included in our series of abscesses, and it is my impression that it was included in the series presented in Tables II and III, with the possible exception of Arbuckle's group of forty-three cases treated by bronchoscopy with a mortality of 0 per cent.

TABLE I. TOTALS

TREATMENT	TOTAL NUMBER	DIED		WELL		CHRONIC	
		NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT
Medical	906	314	34.7	284	31.3	308	34.0
Surgical	744	243	32.7	343	46.1	158	21.2

TABLE II. PULMONARY ABSCESS MORTALITY; SURGICAL TREATMENT

AUTHOR	LOCATION	NUMBER	DIED		WELL		CHRONIC	
			NO.	%	NO.	%	NO.	%
Allen and Blackman*[2]	Detroit	38	15	39.5	20	52.6	3	7.9
Cutler and Gross[5]	Boston	47	22	46.8	16	34.0	9	19.2
Neuhof and Touroff[33]	New York	152	4	2.6	148	97.4	0	0
Shaw and Blackman[41]	Ann Arbor	138	56	40.6	55	40.0	27	19.4
Shaw[41]	Dallas	33	5	15.2	19	57.6	9	27.2
Lueth*[25]	Chicago	23	16	69.6	7	30.4	0	0
Rosenblatt[39]	New York	21	12	57.2	5	23.8	4	19.0
Jackson and Judd[18]	Philadelphia	37	18	48.7	15	40.5	4	10.8
D'Ingianni[9]	New Orleans	141	64	45.4	4	2.8	73	51.8
Overholt and Rumel[34]	Boston	63	13	20.6	35	55.6	15	23.8
Smith	Durham	51	18	35.3	19	37.3	14	27.4
Total		744	243	32.7	343	46.1	158	21.2

*Calculated from data given by the author.

TABLE III. PULMONARY ABSCESS MORTALITY; MEDICAL TREATMENT

AUTHOR	LOCATION	NUMBER	DIED		WELL		CHRONIC	
			NO.	%	NO.	%	NO.	%
Allen and Blackman*[2]	Detroit	55	14	25.5	30	54.5	11	20.0
Cutler and Gross[5]	Boston	36	8	22.2	20	55.6	8	22.2
Shaw and Blackman[41]	Ann Arbor	89	27	30.3	49	55.1	13	14.6
Shaw[41]	Dallas	16	2	12.5	11	68.8	3	18.7
Lueth*[25]	Chicago	73	18	24.7	45	61.6	10	13.7
Rosenblatt[39]	New York	72	34	47.2	4	5.6	34	47.2
Jackson and Judd[18]	Philadelphia	87	23	26.5	33	37.9	31	35.6
Kline and Berger[21]	Cleveland	57	26	45.6	31	54.0	0	0
D'Ingianni[9]	New Orleans	276	141	51.1	8	2.9	127	46.0
Overholt and Rumel[34]	Boston	18	10	55.5	5	27.8	3	16.7
Arbuckle[3]	St. Louis	43	0	0	19	44.2	24	55.8
Smith	Durham	84	11	13.1	29	34.5	44	52.4
Total		906	314	34.7	284	31.3	308	34.0

*Calculated from data given by the author.

MODE OF ONSET

A total of 135 cases of primary pulmonary abscess were admitted to Duke Hospital from 1940 to 1945 inclusive. The mode of onset is shown in Table IV. The number following operations was 37 or 27 per cent. This number has varied from a low of 15 per cent in Rosenblatt's ninety-three cases[39] to a high of 54 per cent in Cutler and Gross' eighty-three cases.[5] There is a general impression in the literature that the prognosis is better in postoperative abscesses than in the nonoperative type. In Cutler and Gross' series with 54 per cent postoperative cases, 36.1 per cent died, 43.4 per cent recovered, and 20.5 per cent remained chronic; but in Rosenblatt's series[39] with 15 per cent postoperative, there was a mortality of 49.5 per cent with only 9.7 per cent well and 40.8 per cent chronic. There were unquestionably factors other than "mode of onset" which determined the greater mortality in Rosenblatt's series.

TABLE IV. MODE OF ONSET

MODE	NO.
Insidious	67
Pneumonic	25
Tonsillectomy	14
Extraction of teeth	11
Other operations	12
Foreign body	6
Total	135

TABLE V. PROGNOSIS BY MODE OF ONSET

		DIED		WELL		CHRONIC	
MODE OF ONSET	NUMBER	NO.	%	NO.	%	NO.	%
Postoperative	37	8	22.0	19	51.0	10	27.0
Postpneumonic	25	8	32.0	6	24.0	11	44.0
Insidious	67	11	16.0	21	31.0	35	53.0
Foreign body	6	2	33.3	2	33.3	2	33.3
Total	135	29	21.4	48	35.6	58	43.0

In Table V there is an analysis of the prognosis by mode of onset in our 135 cases. There are 51 per cent well in the postoperative group in contrast to 35.6 per cent for the group as a whole, but there was a 22 per cent mortality in the postoperative group and only 21.4 per cent for the entire group.

From this and other series it does seem that the postoperative group has a better chance to make a complete recovery than other groups. The improved prognosis may be related more to the shorter duration of the disease when treatment is started rather than to the mode of onset. In our cases the mean duration of the disease was 4.5 months for the entire group and only two months for the postoperative cases.

With the present almost universal treatment of postoperative febrile reactions with penicillin, the number of postoperative abscesses should be materially reduced.

DURATION OF DISEASE

Nearly every writer on the subject of pulmonary abscess has emphasized the importance of early diagnosis and prompt treatment.[26] In Lord's series of 127 cases collected between 1909-1924, there were no spontaneous recoveries after nine weeks.[27] Among the 210 cases reported by King and Lord[20] from 1924-1932, there were thirty-four or 30.9 per cent medical cures in the acute cases of less than two months and only eleven or 11 per cent cures in the 100 cases of more than two months' duration. In the series of Flick and associates[11] of 121 cases, the recovery rate was 70 per cent when the disease was less than three months old. Jackson and Judd[18] obtained their best results with bronchoscopic treatment when the disease was of four to six weeks' duration.

In 1926, Miller and Lambert[30] selected three months' duration as the ideal time for the open drainage of pulmonary abscesses. Before this time the patients have not developed their maximum immunity to the infection, and after three months the progressive fibrosis and dilatation of veins increase the hazards of the operation, both from postoperative hemorrhages and from thrombosis and embolism. With the introduction of sulfonamides and penicillin the spreading infection about the abscess can be controlled and operation can and should be performed much sooner.

Neuhof and Touroff[33] insist that open operation for the drainage of isolated abscesses should be done before the end of the sixth week, and they have treated 152 cases of this type with a mortality of only 2.6 per cent. Lindskog[24] obtained a mortality of 4.5 per cent in twenty-two cases of less than two months' duration, and Overholt and associates[34] a mortality of 6 per cent in thirty-five simple abscesses of less than six weeks' duration.

In 1938, Rives, Major, and Romano[35] analyzed the cause of death in 100 fatal cases of pulmonary abscess and found a death rate of 57 per cent in the acute cases admitted to the hospital during the first four weeks of the disease, only 15 per cent for those admitted between the fourth and eighth weeks and 9 per cent between the second and third months. Since these cases were studied before the introduction of sulfonamides and penicillin, we may assume that they represent the initial high mortality from the disease itself which Miller and Lambert sought to avoid by delaying the operation until the second or third month. Even with the aid of sulfonamides and penicillin, Neuhof and Touroff[33] have advanced the time of operation where they are finding a more acute type of abscess which they call "hyperacute." There have been three deaths (7.3 per cent) in forty-one cases of this "hyperacute" type and only one in the remaining 111 cases of acute single abscesses.

In Table VI is presented an analysis of our 135 cases classified on the basis of the duration of the disease at the time of admission to the hospital. There were thirty-eight cases of less than four weeks' duration. Two of these patients were treated surgically and both died. Of the thirty-six treated medically, five died (14 per cent), nineteen recovered (53 per cent) and twelve improved (33 per cent) but were transferred to surgery for operation. There were no surgical deaths in the five patients operated on between the fifth and twelfth weeks of the disease. Among the twenty-four patients treated medically, one died, six recovered and seventeen were transferred to surgery for operation. Apparently the optimal time for medical treatment is during the first four weeks of the disease, and this must be calculated from the onset of the first febrile reaction and not from the time the first purulent sputum is produced. After the third month of the disease, medical treatment cured only four (5.3 per cent) of the seventy-five cases, while five (6.7 per cent) died and sixty-six (88 per cent) remained chronic.

TABLE VI. PROGNOSIS BY DURATION; 135 CASES

TYPE TREATMENT	LESS THAN 2 WEEKS			2 TO 4 WEEKS			5 WEEKS TO 3 MONTHS			3 TO 6 MONTHS			6 MONTHS TO 1 YEAR			1 YEAR TO 10 YEARS		
	DIED	WELL	CHRONIC	DIED	WELL	CHRONIC	DIED	WELL	CHRONIC	DIED	WELL	CHRONIC	DIED	WELL	CHRONIC	DIED	WELL	CHRONIC
Medical	3	10	3	2	9	9	1	6	17	1	1	31	3	3	20	1	0	15
Surgical	0	0	0	2	0	0	0	2	3	9	6	4	5	6	3	2	5	4

ETIOLOGY

The primary damage to the lung may be chemical from the irritative oils of an aspirated peanut or the effect of gastric secretions aspirated from vomitus, or mechanical from pulmonary thrombosis or infarction or the aspiration of a solid foreign body. In these four instances the infection in the lung is secondary and the prognosis depends to a considerable degree upon the type of secondary invader. Embolic abscesses usually are multiple and a part of a generalized pyemia, but in some instances single isolated abscesses result from infected emboli, particularly from the pelvic veins, and these abscesses cannot be distinguished clinically from the ordinary aspiration type.

A large majority of pulmonary abscesses result from the aspiration of infected material from the patient's own mouth or upper respiratory tract. These aspiration abscesses can be divided into (1) the pyogenic type and (2) the fusospirochetal type.

BACTERIOLOGY

In this series of 135 cases of primary pulmonary abscess, thirty-five were classified as pyogenic and 100 as fusospirochetal (Tables VII and VIII).

Aerobic cultures alone are of very little value in establishing the true cause of an abscess. The aerobic cultures from ten patients with pulmonary tuberculosis, ten patients with pulmonary neoplasm and ten with fungus infections of the lungs were compared. Varying combinations of staphylococci, alpha streptococcus, *Micrococcus catarrhalis* and *Micrococcus pharyngis siccus* were found in all thirty cases. Tubercle bacilli must be eliminated by repeated examinations after concentration of the sputum, actinomycosis by direct examination for sulfur granules, and the yeastlike fungi by cultures on Sabouraud's medium. Every patient with an abscess who is over 40 years of age should be suspected of having a pulmonary neoplasm even when the bronchoscopic examination is negative. Fusiform bacilli should be sought for in smears stained with gentian violet. It is important for the technician to realize that the large fusiform bacillus so characteristic of Vincent's angina usually is absent in cases of pulmonary abscess. One should look for very small, pointed, fusiform bacilli which are practically always present in the fusospirochetal type of abscess. These small fusiform bacilli may be accompanied by the thicker spirochetes *Borrelia buccale* and *B. vincenti.* If fusiform bacilli are present and no spirochetes are seen in the gentian violet preparation, additional examinations should be made with the Fontana stain or the dark-field apparatus to demonstrate the smaller type of spirochetes, *Treponema macrodentium* and *Treponema microdentium,* which are characteristic of the fusospirochetal type of infection. The fusiform bacilli and spirochetes are always accompanied by vibrios, gram-negative bacilli, including *Bacterium melaninogenicum,* and anaerobic gram-positive cocci. *Staphylococcus albus* and *aureus* may or may not be present.

If one has eliminated tuberculosis, neoplasm, fungus infection, and fusospirochetal organisms, and the aerobic cultures contain large numbers of (1) *Staph. aureus,* (2) *Pseudomonas pyocyanea (Bacillus pyocyanea),* (3) colon

TABLE VII. PYOGENIC ABSCESS

NUMBER	SPUTUM	STAPHYLOCOCCUS AUREUS	FRIEDLANDER'S BACILLUS	PYOCYANEUS	SYMBIOTIC ORGANISMS	PEANUTS	SPIROCHETES	FUSIFORM BACILLI	MIXED ORGANISMS
24	Sputum not foul	Pos.	--	--	--	--	Neg.	Neg.	Neg.
1	Sputum not foul	Neg.	Pos.	--	--	--	Neg.	Neg.	Neg.
1	Sputum not foul	Pos.	Pos.	Neg.	--	--	Neg.	Neg.	Neg.
1	Sputum not foul	Neg.	Neg.	Neg.	Pos.	--	Neg.	Neg.	Neg.
2	Sputum not foul	--	--	--	--	Pos.	Neg.	Neg.	Neg.
5	Empyema not foul	Pos.	--	--	--	--	Neg.	Neg.	Neg.
1	Empyema foul	Neg.	Neg.	Pos.	--	--	Neg.	Neg.	Neg.
Total 35									

TABLE VIII. FUSOSPIROCHETAL ABSCESS

NUMBER	SPUTUM	SPIROCHETES	FUSIFORM BACILLI	STAPHYLOCOCCUS AUREUS	MIXED ORGANISMS
53	Sputum foul	Positive	Positive	Negative	Positive
6	Sputum foul	Positive	Positive	Positive	Positive
7	Sputum foul	Negative	Positive	Negative	Positive
1	Sputum foul	Negative	Positive	Positive	Positive
4	Empyema foul	Positive	Positive	Negative	Positive
3	Empyema foul	No examination	--------	--------	--------
10	Sputum foul	By history	No examination	--------	--------
5	Sputum not foul	Positive	Positive	Negative	Positive
5	Sputum not foul	Negative	Positive	Negative	Positive
6	Diagnosis by operation or necropsy				
Total 100					

bacillus, (4) *Proteus* or (5) *gas gangrene organisms, we can conclude that the* patient has a pyogenic abscess.

The pioneer studies of Kline[21] in Cleveland, Pilot and Davis[35] in Chicago, and Smith[42, 45] in the Adirondacks between 1920 and 1930 established the frequency and importance of the fusospirochetal type of organism as the cause of pulmonary abscess. Kline[21] and Smith[43] found the fusospirochetal type of infection in 90 per cent of abscesses in adults but in only 50 per cent of abscesses in children. This group of fusospirochetal and accompanying anaerobic organisms gives the characteristic fetid odor to the sputum of abscessed patients although occasionally the foul odor is caused by (1) colon bacilli, (2) *Proteus,* (3) *Pseudomonas pyocyanea,* or (4) gas gangrene organisms.

The multiplicity of organisms present in the fusospirochetal type of abscess has resulted in considerable skepticism on the part of the medical profession in accepting this as a specific type of infection. There is no question that this group of organisms as a unit can reproduce in experimental animals the typical clinical and pathologic picture of primary pulmonary abscess. Experimental lesions of this type have been produced by Kline,[22] Smith,[44, 47] Crowe and Scarff,[7] Allen,[1] Hedblom, Joannides, and Rosenthal,[16] Harkavy,[15] Van Allen, Adams, and Hrdina,[32] Herrmann and Cutler,[17] Lambert and Weeks,[23] Bethune,[5] Hamilton,[14] Longacre and Herrmann,[25] and Weiss and Shevky.[65]

This sharp difference of opinion as to the value of arsenical therapy can be explained in part by the type of case treated in the different series. Practically all of the good results have been obtained in the first eight weeks of the disease and the best results in the first ten days when the infection was still in the pneumonic stage with the circulation intact and before any appreciable necrosis of the lungs had occurred. Arsenicals are palliative only in cases of more than three months' duration.

SULFONAMIDE THERAPY

Sulfonamides have a bacteriostatic effect on the gram-positive organisms but no effect on the spirochetes and fusiform bacilli. One would expect a sharp difference in results between pyogenic abscesses and fusospirochetal abscesses. Table IX shows our results in ten cases of pyogenic abscess and twenty-four cases of fusospirochetal abscess. There was only one death and six recoveries in the pyogenic group, while there were three deaths and only two recoveries in the fusospirochetal group, although in most instances the sulfonamides were given within twenty-four to forty-eight hours after the appearance of the first febrile reaction. In D'Ingianni's series[9] there was a death rate of 58.6 per cent in patients treated with sulfonamides as compared with 49.1 per cent for the entire group: on the other hand, the patients receiving arsenicals or bismuth had a death rate of only 34.2 per cent.

In our experience, sulfonamide therapy for the fusospirochetal type of infection has been harmful in an indirect manner. Patients in the early pneumonic stage of the disease usually show marked temporary improvement which encourages continuation of the therapy; then later they develop necrotic abscesses which will no longer respond either to sulfonamides, arsenicals, or penicillin, and require surgical treatment.

TABLE IX. SULFONAMIDE THERAPY

TYPE ABSCESS	NUMBER	DIED	WELL	CHRONIC	FOUL SPUTUM
Pyogenic	10	1	6	3	0
Fusospirochetal	24	3	2	19	16

TABLE X. PENICILLIN THERAPY

TYPE ABSCESS	NUMBER	DIED	WELL	CHRONIC
Multiple metastatic	7	3	4	0
Pyogenic	3	0	2	1
Putrid or mixed	50	7	32	11
Total	60	10 (16.7%)	38 (63.3%)	12 (20%)

PENICILLIN TREATMENT

Theoretically, penicillin therapy should be ideal for both the pyogenic abscess caused by gram-positive cocci and the fusospirochetal type of abscess, because penicillin is more effective against gram-positive cocci than sulfonamides and is quite as efficient as arsenicals in eliminating spirochetes. Smyth and Billingslea[48] collected thirty-one cases of pulmonary abscess from the literature and added four of their own. Meleney, Friedman, and Harvey[29] treated one case with penicillin in which there was a *Clostridium welchii* infection. Stivelman and Kavee[49] report the recovery of five of six acute putrid abscesses following penicillin therapy. Nineteen of the patients in our series were treated with penicillin. Table X shows the results of penicillin in these sixty collected cases. The results are very encouraging. For the early incipient stage of the infection, penicillin is certainly the drug of choice (Figs. 1, 2, and 3), but it is not effective in the chronic cases although the patients may improve to a point where they are better surgical risks.

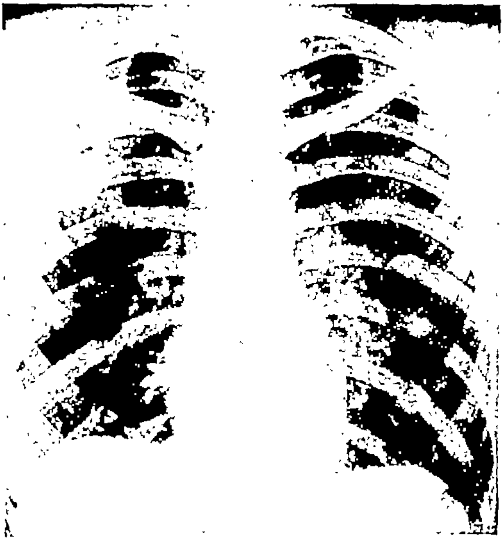

Fig. 1.—The x-ray film shows a pneumonic process in the outer two-thirds of the right upper lobe which contains a large thin-walled cavity with fluid level. The patient had putrid sputum which contained fusiform bacilli, spirochetes, vibrios and cocci. Penicillin therapy in doses of 20,000 units every three hours was started during the second week of the disease, dating the onset from the first appearance of fever.

Recent reports[4, 40, 53] of penicillin inhalations indicate that patients with chronic abscess and bronchiectasis obtain striking temporary improvement which makes them better operative risks, but the chronic type of the disease cannot be cured by this treatment.

MEDICAL TREATMENT OF CHRONIC PULMONARY ABSCESS

The ineffectiveness of medical treatment in chronic pulmonary abscess has already been discussed in the section on the duration of the disease. There is an occasional case in which operation is contraindicated or where operation is refused by the patient and the medical man must attempt treatment. A case of this type is illustrated in the following report.

CASE REPORT

CASE 1.—Mrs. G. F. L., aged 20, had her tonsils removed July 13, 1942, under a general anesthetic. Some bleeding occurred at the time of the operation, and the patient vomited dark blood the next day. The patient was discharged three days after tonsillectomy. A week later, while attending a picnic, she was caught in a summer shower and developed a cough. This dry cough became progressively worse during the next two weeks, but the patient continued her work in a hat shop for another week, when the development of fever and malaise necessitated confinement to bed. She began to notice pain in the right side about this time. After three days in bed she was admitted to a local hospital and treated with sulfonamides for twelve days. The cough was now productive of a very small amount of purulent sputum, and films of her chest showed a pneumonic process in the center of the right lung field (Fig. 4). Her general condition improved while she was in the hospital, but all symptoms returned with greater intensity after her return home. Vitamins, one blood transfusion, and local applications of heat to the right side did not relieve her symptoms.

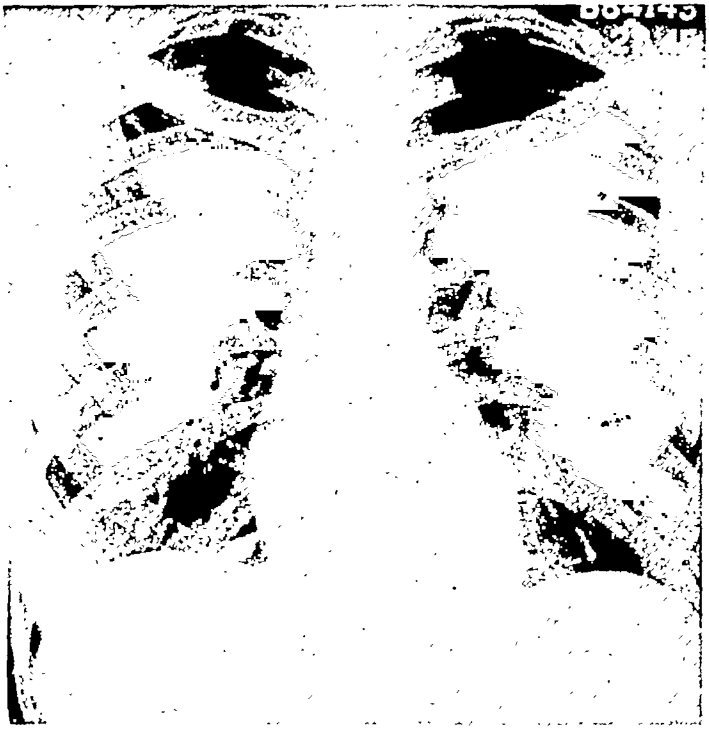

Fig. 2.—The x-ray film is of the same patient as shown in Fig. 1, four weeks after penicillin treatment was started. The parenchymal involvement has been absorbed, but the thin-walled cavity can still be seen in the right upper lobe. The patient was afebrile and there was no sputum at this time.

On Oct. 2, 1942, about eleven weeks after the tonsillectomy, a rib was resected and drainage tubes inserted by a local surgeon. Very little material drained through the tubes; her cough became paroxysmal and produced ounces of foul, purulent sputum. She developed high spiking temperature accompanied by nausea.

About Nov. 2, 1942, the pulmonary abscess was drained under local anesthesia, through the original thoracotomy wound. She remained critically ill for the next six weeks and then began to improve. Postural drainage and general supportive treatment, including twelve blood transfusions, were used between September 3 and January 17.

The patient was discharged from the hospital April 15, approximately six months after the first operation on her lung. The sinus in the chest was discharging small amounts of material and her cough, although no longer paroxysmal in character, still produced about three ounces of purulent sputum daily. She continued to improve during the summer of 1943 and the sinus in the chest wall closed about the last of August, but the productive cough persisted. In September, 1943, she had three severe hemorrhages and was again hospitalized for fifteen days.

She remained at home from September, 1943, until she came to Duke Hospital April 4, 1944, twenty months after tonsillectomy. During the interval her general condition gradually improved, but she continued producing two to three ounces of foul, purulent sputum which occasionally contained blood. She had been ambulatory during the past six months and usually afebrile, but had frequent recurring "colds" with exacerbation of symptoms.

On physical examination April 4, 1944, the patient was found to be a well-nourished, well-developed young woman of 22 years who seemed to be suffering from chronic malaise but was not acutely ill. A constant harassing, productive cough was the predominant symptom. There was moderate clubbing of the fingers and toes and a healed scar in the right axilla. With these exceptions, all of the positive physical findings were limited to her chest. Dullness, increased tactile fremitus and whispered voice, and prolonged expiration were present over the region of the right upper lobe. Râles were present over the lower half of this area. Roentgenograms of the chest showed the right leaf of the diaphragm elevated and the presence of a dense zone of fibrosis extending from the right hilum to the chest wall, presumably in the lower part of the right upper lobe (Fig. 5).

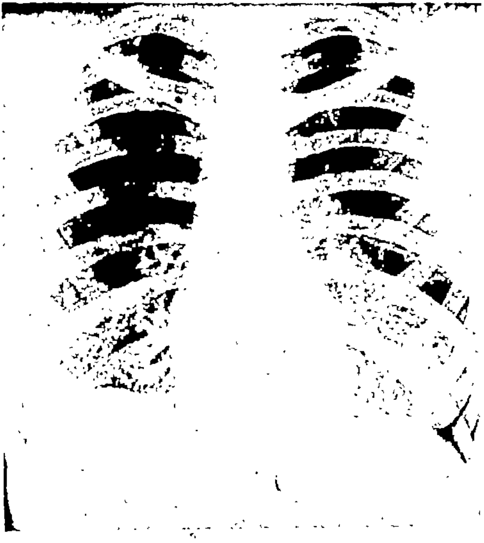

Fig. 3.—This film shows the same patient three months later. There has been a complete disappearance of the shadows from the right upper lobe, and the patient is entirely well.

Laboratory examination showed the Kahn, Kline, and Mazzini tests negative. The urine was normal. Her hemoglobin was 13.5 Gm. or 87 per cent with a white blood count of 8,500 and a differential count of segmented polymorphonuclears 65 per cent, eosinophiles 0, basophiles 0, monocytes 1 per cent, large lymphocytes 2 per cent, and small lymphocytes 32 per cent. The sputum was purulent, greenish in color, and foul in odor. It was negative for acid-fast organisms but contained numerous gram-positive and gram-negative cocci and bacilli, numerous vibrios and fusiform bacilli, and moderate numbers of spirochetes of the *T. macrodentium* and *T. microdentium* types.

Diagnosis.—The diagnosis of chronic pulmonary abscess of the fusospirochetal variety was made and lobectomy was advised. The patient emphatically refused to consider an operation and requested medical treatment although she was told that improvement with medical treatment was very unlikely and a cure practically impossible.

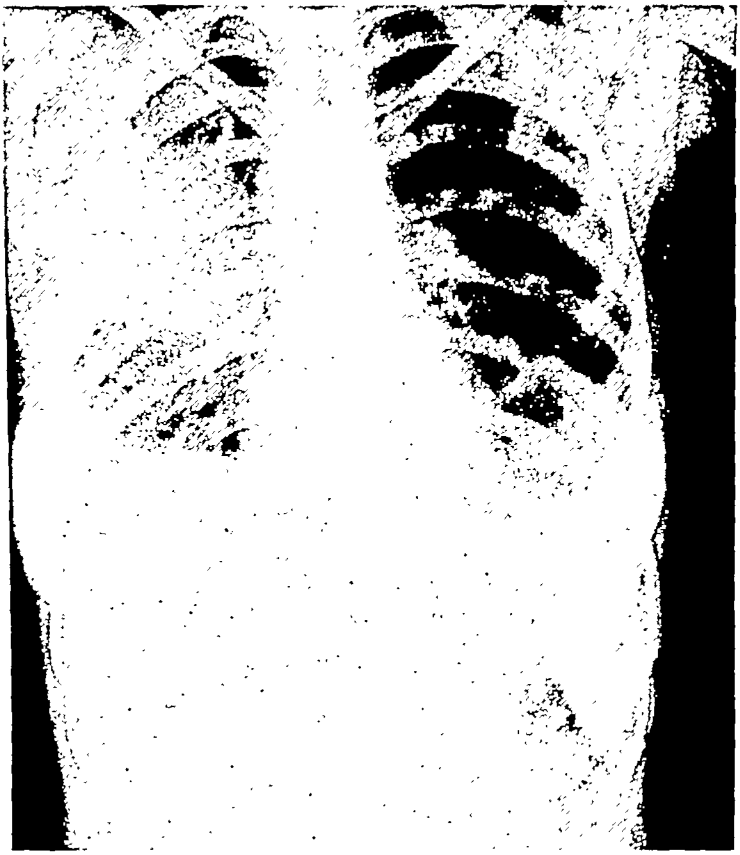

Fig. 4.—Case 1. The x-ray film shows a dense pneumonic process in the central portion of the right lung field. This infection failed to respond to sulfonamides and progressed to definite cavity formation which necessitated open operation and drainage.

I wish to thank Dr. R. B. Davis, of Greensboro, N. C., for permission to use this film.

Treatment.—The treatment in this case of chronic fusospirochetal pulmonary abscess was long and complicated and was characterized by the application of a number of well-known medical procedures in a definite sequence. In previous cases, none of these procedures either alone or in haphazard combination gave more than partial or temporary improvement. The patient remained ambulatory, returning to the hospital at frequent intervals for examination and treatment for the first six weeks and then at biweekly, monthly, and finally three-month intervals for the remainder of the period of treatment. Postural drainage, which had been employed for eighteen months, was continued and vitamins and iron were added to the diet. No restrictions were made to her previous routine of living.

An autogenous vaccine was prepared from a mixture of the anaerobic organisms grown from her sputum. Intradermal skin tests revealed that she was definitely sensitive to this mixture. Desensitization by subcutaneous injection with a dose which gave neither local nor constitutional reaction was begun. The dose was increased by 0.1 c.c. three times each week and continued for six weeks.

Sulfadiazine in doses of 1 Gm. every four hours except during the period of sleep at night was started and continued for thirty days.

Neoarsphenamine in 0.6 Gm. doses was administered intravenously each week for six weeks.

After four weeks of desensitization with the vaccine and thirty days of sulfadiazine, potassium iodide therapy was started. A saturated solution of potassium iodide was employed and the initial dose was 1 drop three times a day in one ounce of water. The potassium iodide was increased by one drop each day, *not one drop each dose*. The patient was told that the iodide was being given to accelerate the absorption of the granulomatous tissue in the diseased area and that hemoptysis might occur as the dose was increased. She was instructed to discontinue the potassium iodide if blood were seen in the sputum, remain in bed for forty-eight hours after the sputum was free of blood, and then begin the potassium iodide again with the initial dose of 1 drop three times a day. Hemoptysis did occur on four different occasions during the next four months at a dose level of 6 to 10 drops of potassium iodide three times daily. Possibly because of the previous explanation and warning, the patient was not at all alarmed by the hemoptyses.

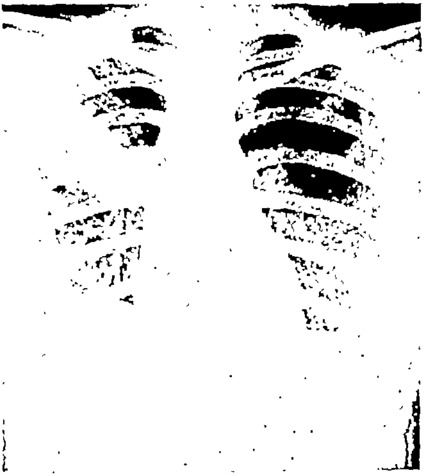

Fig. 5.—Case 1. This film shows a dense process in the lower part of the right upper lobe which is the residue of infection after twenty months of treatment, including *open* operation and drainage.

By May 18, 1944, six weeks after treatment began, the patient was feeling somewhat better. The sputum was reduced by 10 per cent and had lost the foul odor, but there were no changes in the physical findings or in the film of the chest.

After another month of treatment, on June 17, 1944, the patient reported that she felt much better. The sputum was reduced by 25 per cent and now had a yellowish tinge instead of the original greenish color. There were fewer râles in the right upper lobe, but the film of the chest remained unchanged.

By July 17, 1944, the patient seemed much stronger. The sputum was reduced by another 25 per cent and was produced almost exclusively by postural drainage. Fewer râles were heard in the right upper lobe, and films of the chest showed a 25 per cent reduction in the size of the lesion. Since the patient was no longer having hemoptyses, the dose of iodides reached the maximum of 20 drops three times a day; then it was reduced to 3 drops three *times a day and again carried up to the maximum of 20 drops three times daily.* This procedure of increasing and decreasing the dose was continued throughout the period of treatment.

After another three months, on Nov. 1, 1944, the patient looked fine and the sputum was reduced to 8 c.c. daily. There was a striking reduction in dullness noted in the right upper lobe, and only an occasional râle could be elicited by an expiratory cough. There was an additional 10 per cent reduction in the size of the lesion by x-ray.

Films of the chest made Jan. 10, 1945, showed increasing fibrotic changes in the lesion with some slight reduction in the size of the diseased area.

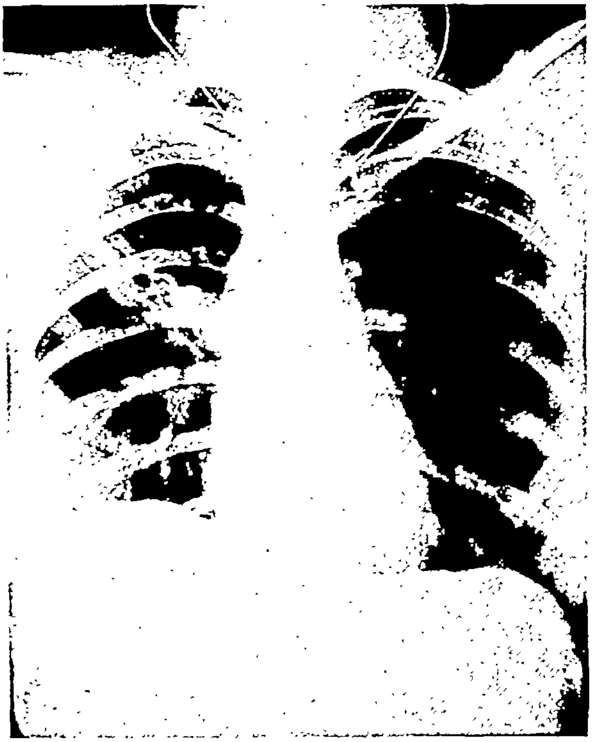

Fig. 6.—Case 1. This chest film was made fourteen months after medical treatment was started in this case. There is still some dense fibrous tissue present in the lower portion of the right upper lobe and some areas of decreased density which suggest multiple cavity formation although the patient has had no cough or sputum for many months. Another film made six months later showed the same findings.

After approximately one year of treatment the patient reported March 3, 1945, that she felt even better than she did before the original tonsillectomy. She had no cough, no sputum, and not even a cold during the past winter. The fibrous lesion in the lung was unchanged by x-ray (Fig. 6).

Potassium iodide therapy was discontinued June 30, 1945. The patient was in excellent condition and had no cough or sputum.

The patient was still well and free of all symptoms when examined Dec. 5, 1945, although the residual fibrous lesion in the lung persisted unchanged.

Summary of Case.—A young married woman of 20 years of age developed a pulmonary abscess after tonsillectomy. The infection was not controlled by sulfonamide therapy, and the abscess was drained through the chest wall fifteen weeks after the tonsillectomy; she was critically ill for six weeks and remained in the hospital for six months. At the time of discharge the operative wound was still draining and she was raising three ounces of purulent sputum daily. The sinus in the chest wall closed four months later, but she remained chronically ill with purulent sputum and occasional hemoptyses for the next eight months.

She was examined at Duke Hospital twenty months after the original tonsillectomy, where a lobectomy was advised but refused by the patient.

The medical treatment given this case of chronic pulmonary abscess consisted of: (1) desensitization over a 45-day period with a vaccine prepared from anaerobic organisms grown from her sputum; (2) sulfadiazine for thirty days; (3) neoarsphenamine in 0.6 Gm. doses each week for six weeks, followed by (4) potassium iodide therapy for fourteen months. Hemoptysis occurred four times during the first four months of the iodide therapy at a dose level of 6 to 8 drops three times a day, but did not recur with 20 drops three times a day taken in the course of the treatment when the sputum was scant in amount and the pulmonary lesion was fibrotic.

The patient has been in excellent condition for eight months, free of cough and sputum, but still has a fibrous scar in the lung.

DISCUSSION

The prognosis in pulmonary abscess depends upon a number of factors, such as the type of abscess, whether single and peripheral or multiple and complicated by bronchiectasis; whether the infection is a primary aspiration or secondary to chemical irritation from a peanut or gastric secretions, or mechanical from pulmonary thrombosis and infarction or aspiration of a solid foreign body. The type of bacterial infection alters the prognosis and necessitates certain modifications in treatment. Our experience coincides with that of Touroff and Neuhof[31] who state that nonputrid pyogenic abscesses respond poorly to open drainage. In this group belongs the type of case which Neuhof and Thomas[31] call "suppurative bronchopneumonia." These patients should be treated with sulfonamides and penicillin and lobectomies or pneumonectomies performed if satisfactory improvement does not result. Most of our cases following aspiration of peanuts have required lobectomies.

Abscesses of the fusospirochetal type should be diagnosed in the first week or ten days of the disease, dating the onset from the first febrile rise, and treated intensively with penicillin with or without supplementary arsenicals, sulfonamides, or streptomycin. If the patients do not make dramatic improvement, they should be operated on before the end of the sixth week. Clinical improvement alone should not be accepted as a satisfactory criterion. There should be a progressive clearing of the pulmonary shadows and the patient should be followed until the lungs are clear by chest roentgenogram.

In general, the medical treatment of acute pulmonary abscesses has been distressingly bad during the past ten years. The errors have been primarily those of the internist rather than the thoracic surgeon. The internist too frequently has failed to determine the etiologic agent responsible for the pulmonary abscess; has often given inadequate treatment; and when the patient has made a partial recovery, has prolonged the medical treatment to a point where the patient becomes a poor surgical risk.

In Table II is presented the results of surgical treatment and in Table III the results of medical treatment. The mortality of 32.7 per cent for the patients treated surgically is not much better than the medical mortality of 34.7 per cent. Certainly a considerable part of this relatively high surgical mortality has resulted from the poor medical treatment given prior to operation.

A better idea of the results of medical treatment can be obtained by considering all patients in Tables II and III as being medical patients before they underwent operation. In Table XI we have added the patients who received surgical treatment to those who received nothing but medical treatment and recalculated the results. For example, Allen and Blackman report fifty-five patients as receiving medical treatment alone and thirty-eight as receiving surgical treatment, or a total of ninety-three; but certainly the thirty-eight received—or failed to receive—some kind of medical therapy prior to operation. In this group of 1,498 patients listed in Table XI, the mortality from medical treatment is 21 per cent in contrast to a mortality of 34.7 per cent as shown in Table III. The recoveries, on the other hand, are only 19 per cent in contrast to 31.3 per cent as recorded in Table III. The most significant finding is the 60 per cent of this series of 1,498 patients who were still chronically ill after medical treatment. Seven hundred and forty-four of these were then transferred to the surgical departments for operation with the results recorded in Table II. Not only is the percentage of failures greater with medical treatment, but the patients are generally in much poorer condition and usually are not able to work, while many of the patients listed as chronic after surgery have only minor disability and are able to earn their living.

TABLE XI. PULMONARY ABSCESS MORTALITY; MEDICAL TREATMENT

AUTHOR	LOCATION	NUMBER	DIED		WELL		CHRONIC	
			NO.	%	NO.	%	NO.	%
Allen and Blackman*[2]	Detroit	93	14	15.0	30	32.3	49	52.7
Cutler and Gross[8]	Boston	83	8	9.6	20	24.1	55	66.3
Shaw and Blackman[41]	Ann Arbor	227	27	11.9	49	21.6	151	66.5
Shaw[41]	Dallas	49	2	4.1	11	22.4	36	73.5
Lueth*[28]	Chicago	96	18	18.7	45	46.9	33	34.4
Rosenblatt[30]	New York	93	34	36.6	4	4.3	55	59.1
Jackson and Judd[18]	Philadelphia	124	23	18.6	33	26.6	68	54.8
Kline and Berger[21]	Cleveland	57	26	45.6	31	54.4	0	0
D'Ingianni[9]	New Orleans	417	141	33.8	8	1.9	268	64.3
Overholt and Rumel[34]	Boston	81	10	12.3	5	6.2	66	81.5
Arbuckle[3]	St. Louis	43	0	0	19	44.2	24	55.8
Smith	Durham	135	11	8.1	29	21.5	95	70.4
Total		1498	314	21.0	284	19.0	900	60.0

*Calculated from data given by the author.

One case of chronic pulmonary abscess of the fusospirochetal type is reported where the treatment consisted of sulfonamide therapy, neoarsphenamine injections, desensitization with an autogenous vaccine, followed by the administration of potassium iodide. Since occasionally patients with chronic abscesses make a complete recovery, no conclusions can be drawn from this isolated case.

CONCLUSIONS

1. The mortality in a series of 2,166 cases of pulmonary abscess collected from representative clinics from 1936 through 1944 was 32.7 per cent.

2. Early medical diagnosis of the pneumonic infiltration which precedes the abscess is essential for successful treatment with penicillin, arsenicals, or streptomycin.

3. Sulfonamide therapy definitely is helpful in pulmonary abscesses caused by gram-positive cocci.

4. Sulfonamide therapy in the fusospirochetal types of infection gives temporary improvement but fails to cure, and the patient's progress to chronic abscesses which will not respond to penicillin or arsenicals.

5. If the patient is not improving clinically and clearing steadily, as shown in serial x-ray films, by the end of the fourth to sixth week of the disease, he should be referred to the thoracic surgeon for operation.

6. Inadequate early treatment and prolongation of medical treatment past the optimal time for operation are the chief causes for the high mortality from pulmonary abscess.

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THORACIC CASUALTIES FROM AN ISLAND CAMPAIGN IN THE PACIFIC

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THIS study concerns 172 battle casualties receiving thoracic wounds in the final campaign in the Pacific. Only patients with wounds penetrating the pleura are included. They represent all the thoracic wounded passing through the central Pacific from this campaign receiving wounds penetrating the pleura.

The number of men with thoracic wounds dying in division or field hospitals is not known.

No evacuation hospitals were in the chain of evacuation. Early definitive treatment was carried out in the field hospitals and on board hospital ships. Evacuation was by ship and plane 1,600 miles to forward general hospitals, Army Station hospitals and Navy Base hospitals, thence by air or ship to the thoracic center in the central Pacific, a distance of 4,000 miles.

This record of the treatment and evacuation of thoracic casualties is not offered as an ideal system. It simply illustrates the tremendous problems which arose in the Pacific due to the great distances to be covered. No trained thoracic surgical teams were available for early definitive treatment. In the four general and base hospitals supplying the middle link in the chain of evacuation, there were only two surgeons with appreciable training in thoracic surgery.

It will be noted in Table I, that the number of wounds from high explosives and from bullets in this campaign differs from that in other theaters.[1]

To use the classification of Welch and Tuhy[2] there were twelve thoracoabdominal wounds, five thoracoretroperitoneal wounds (two of which are uncertain) and no abdominothoracic wounds, making a total of seventeen (9.9 per cent) wounds that penetrated the diaphragm.

A history of hemoptysis was obtained in 129 (75 per cent of the patients which lasted on the average of 4.6 days per patient. All but two cases had a history of dyspnea varying from one to fifty days; the average being 12.7 days. X-ray evidence of pneumothorax was present in forty-two (24.4 per cent) casualties. There were two (1.2 per cent) casualties with tension pneumothorax. One was treated with a flutter valve and the other by repeated aspiration. Hemothorax was present in 166 casualties. In seventy-five (43.6 per cent) it was less than one-third and in ninety-one (53.9 per cent) it was over one-third.

TREATMENT IN DIVISION

The Division Medical Services gave 41 units of whole blood to twenty-six (15.0 per cent) casualties, an average of 1.6 units of blood per patient. They gave 141 units of plasma to eighty (46.5 per cent) casualties, an average of

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Read (by title) at the Twenty-Sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30, and 31, 1946.

TABLE I. TYPE OF WOUNDS

WOUND			SUCKING		RIB FRACTURE		
TYPE	NO.	%	NO.	%	NO.	%	NO. RIBS
High Explosive	96	55.8	62	64.6	28	29.1	38
Perforating	3						(1.3 Avc.)
Penetrating	93		50	66.6	40	53.3	
Bullet	75	43.6					
Perforating	65						73
Penetrating	10						(1.8 Avc.)
Bayonet	1	0.1	1	0.1	0		

1.8 units of plasma per patient. Five thoracenteses were done in the clearing stations on four (2.3 per cent) casualties with an average of 500 c.c. of blood being withdrawn per aspiration. In one patient an air flutter valve was inserted to relieve tension pneumothorax. There were seventy-nine casualties with sucking wounds that had pressure dressings applied.

The average elapsed time between the hour of wounding and arrival at a field hospital was 6.8 hours. If ten casualties were to be admitted that were delayed for long periods of time due to the intensity of the battle or because they were wounded in remote areas, then the average evacuation time for those remaining would be 5.4 hours. It is interesting to note that in addition to the traditional litter-ambulance method of evacuation, two casualties were evacuated on LSTs and three were evacuated by liaison planes.

TREATMENT AT FIELD HOSPITALS

Under this heading will also be included all treatment given by hospital ships which early in the campaign took casualties directly from the Division Medical Service or soon after their admission to the field hospitals because of the congestion that existed there.

Ninety-four (54.6 per cent) casualties received a total of 226 thoracenteses an average of 2.4 aspirations per patient with an average amount of 367.4 c.c. being withdrawn per aspiration. (Note in twenty-three instances the amount withdrawn was not recorded). All but twenty-four (13.9 per cent) of the wounds were debrided, of which nineteen were due to high explosive fragments and nine were due to bullets. Of the 144 wounds that were debrided, ninety-nine (57.6 per cent) were primarily sutured. The remainder had petrolatum gauze packs or dressings applied. Of the ninety-nine patients receiving primary suture, the defect was so large in thirteen patients that a muscle flap was used to close the defect. In this group of thirteen patients, four subsequently developed empyema, which in two of the cases apparently was due to an infection and breakdown of the closure with the formation of a pleurocutaneous sinus. Also in this group of thirteen muscle flap closures two patients developed an atalectasis and another clotted hemothorax.

The records were not sufficiently detailed to permit an analysis of the thoracotomies done at the field hospitals. There were seven recorded. One was for the removal of a metallic foreign body. The other six consisted of an enlargement of the wound for the removal of shattered rib fragments. It is believed that there were more, for several of the healed scars suggested that a limited thoracotomy had been done.

Laparotomies were done on nine (5.2 per cent) patients because associated intraabdominal wounds were suspected. Of these nine laparotomies, four patients had wounds of the liver that were repaired, two had high explosive fragments removed from the abdominal cavity (location not given) and in three no details of the laparotomy accompanied the patient. In four cases lacerations of the diaphragm were sutured. There were eight other patients with thoracoabdominal wounds who did not receive laparotomies. These x-ray plates showed that six had small high explosive fragments in the liver. In one the fragment was in the body of a lumbar vertebra and in another a bullet was adjacent to the body of a lumbar vertebra.

There were eight metallic foreign bodies removed. Three of these were removed from the abdomen at the time of laparotomy. Four others were removed from the chest wall (each of these had previously traversed the thoracic cavity). One thoracotomy was done for the removal of a metallic foreign body.

The value of intercostal nerve blocks to control pain has been mentioned by Blades,[3] Snyder,[4] and others. In this group of cases it was done only once at one of the field hospitals.

There were 111 (64.5 per cent) cases that received 356 units of blood an average of 3.2 units per case and sixty (34.9 per cent) cases that received 99 units of plasma, an average of 1.6 units per case. There is no mention made in the records that any of the blood aspirated from the hemothoraces was used for autotransfusion. There were eight (4.7 per cent) casualties whose only treatment was a dressing before they were evacuated.

During the earlier phases of the campaign, patients were evacuated chiefly by hospital ship, but as the air transport service became better organized during the campaign, the majority were evacuated by air to forward bases on islands 1,600 miles away. The usual flight was between 8,000 and 11,000 feet. There were 104 patients evacuated by ship and sixty-eight by air transport. Of those sixty-eight going by air, nineteen complained of slight dyspnea at some time during the trip, eighteen noted moderate dyspnea, and in five patients the dyspnea was severe, requiring oxygen for relief. These casualties reached the forward bases on an average of 9.1 days following their injury.

TREATMENT AT GENERAL HOSPITALS ON FORWARD BASES

In sixty (34.9 per cent) patients it was found that treatment in the forward areas had been adequate so that only convalescent care was needed at these general hospitals. Fifty (29.1 per cent) patients were given 139 units of blood, an average of 2.8 units per case. There were 239 thoracenteses done on ninety casualties, making an average of 2.7 aspirations per patient. An average amount of 404.8 c.c. was withdrawn per aspiration.

Five patients with empyema had a rib resected to establish open drainage. Four of these were eventually evacuated to the mainland for further treatment. The lung of the fifth patient completely re-expanded and he was discharged to duty. Six casualties had foreign bodies removed. Three were removed by elective thoracotomy, one from the chest wall, one at the time of a decortication, and one through an esophagoscope. All were sent to duty without complications except one who developed a postoperative collapse of the entire left lung. Re-expansion was obtained only after a decortication was done at this thoracic center.

Decortications were done on four casualties. In three a good result was obtained and they were returned to duty. The fourth arrived at the thoracic center with an infected sinus in his chest wall due to the presence of a neglected drainage catheter. The lung completely expanded, the infection subsided, and the sinus closed while the patient was in this hospital.

Evacuation to the central pacific thoracic center, 4,000 miles, was usually by air, either continuoss, stopping only for gas twice, or with one stop of a few hours at about the middle of the trip. The usual flight was between 8,000 and 11,000 feet. There were 149 casualties evacuated by air and twenty-three by ship. Of those evacuated by air, thirty-four complained of slight dyspnea at some time during the trip, eleven noted moderate dyspnea, and six were severely dyspneic, requiring oxygen for relief. Casualties arrived at the thoracic center on an average of 39.7 days following their injury.

TREATMENT AT THORACIC CENTER OVERSEAS

Convalescent care only was necessary for 112 (65.1 per cent) of the patients. There were thirty-four patients in this group who had a residual hemothorax which required an average period of 24.8 days to complete its absorption before the patient could be returned to duty. Thirty-eight (22.1 per cent) casualties required an average of 3.1 thoracenteses. Transfusions of whole blood were given to sixteen (9.3 per cent) cases, an average of 3.2 units being given per patient. Delayed wound closures were done on sixteen (9.3 per cent) patients.

There were twenty-seven foreign bodies removed; thirteen by elective thoracotomy, eight at the time of decortication, and six were removed from the chest wall. Fourteen patients required a decortication; ten for clotted hemothorax, and four for empyema. Two cases had an open drainage for massive empyemas.

FOREIGN BODIES

A summary of the treatment of foreign bodies in this series indicates that a total of forty-one foreign bodies were removed from the following locations; lung fifteen, chest wall eleven, mediastinum two, heart wall one, lung or pleural cavity during decortication nine, and abdomen at the time of laparotomy three. One or more of the following indications for removal existed; large size (over 1.5 cm. in diameter) twenty-three proximity to vital structures four, sharp, irregular edges four, small abscess, about the foreign body three, hemoptysis two, foreign body in an empyema cavity two, and pain and cough one.

Twenty-two of these patients had good results and were returned to duty. The remaining nineteen were evacuated to the mainland; eleven for other disability not connected with the chest wound, seven for convalescence following a decortication and one because of dyspnea and easy fatigability. One developed a bronchopleural fistula and on admission to the thoracic center he had a total collapse of his left lung. This responded well to decortication.

Thirty-two casualties were discharged to duty with small retained metallic foreign bodies. There were seventeen more with retained metallic foreign bodies that were evacuated to the mainland; seven for further observation and ten for reasons not related to the retained foreign body.

HEMOTHORAX

In this series of cases it is noted that fifty-two casualties received thoracenteses on the first day of their injury, fourteen on the second day, seven on the third day, eleven on the fourth day, five on the fifth day, four on the sixth day, twenty-five on the seventh to fourteenth days, thirteen on the fourteenth to twenty-first days, and six on the twenty-first to fifty-sixth days. There were thirty-five casualties that had no thoracenteses. There is nothing to indicate that bleeding was reactivated because of early thoracenteses in any of these patients. There was no intentional air replacement of the aspirated blood at the time of thoracenteses, which is in accord with the current feeling.[1, 5, 6] By the time that these casualties reached the thoracic center, the hemothorax in most cases was stabilized and undergoing absorption. There were thirty-four patients with small hemothoraces who required an average of 24.8 days to absorb the remainder of their fluid. In twenty-five more hemothoraces the fluid cleared with a combination of aspiration and absorption.

There were eighteen patients who received decortications. A brief summary of these cases appears in Table II.

The decortications were done on the average of 5.5 weeks after injury. The shortest interval was two weeks and the longest was eleven weeks following injury. No particular technical difficulties were experienced in doing the decortications which is in agreement with the experience of Churchill,[2] Tuttle and associates,[7] Lush and associates,[9] Samson and associates[12] and others. Good results were obtained in fourteen cases. Two patients had good re-expansion of their lung but their convalescence was prolonged and at the time of evacuation they continued to have a decreased expansion of the chest on the injured side. Two poor results were obtained; one patient had a considerable amount of deformity of the chest wall with a markedly thickened pleura and the other had a persisting bronchopleural fistula with partial collapse of the injured lung. Seven of these patients were discharged to duty, nine were transferred to the mainland for convalescent care only, and two were evacuated for further treatment.

EMPYEMA

In this series thirteen patients had frank infection of their hemothoraces. This is an incidence of 7.6 per cent which compares very favorably with the reports of Tuttle and associates, (16.8 per cent),[7] Nicholson and Scadding (33 per cent),[8] Burford (11.2 per cent), [10] and Pain and Plankers (11.0 per cent).[11] A summary of these thirteen empyemas is presented in Table III.

TABLE II. SUMMARY OF CASES TREATED BY DECORTICATION

	CASE																			
Wound	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	TOTAL	%
Penetrating	B	–	H	–	H	H	H	H	–	H	H	H	B	H	H	H	H	H	15	83.3
Perforating	–	B	–	B	–	–	–	–	B	–	–	–	–	–	–	–	–	–	3	16.7
Sucking	1	1	1	–	1	–	1	1	–	1	1	1	1	1	–	1	1	1	14	77.7
Pneumothorax	1	?	–	–	1	–	1	?	–	1	–	1	1	?	1	?	1	1	9	50.0
No. fractured ribs	2	–	–	2	–	–	–	1	5	–	–	1	1	–	–	–	1	–	7	38.9
Days of hemoptysis	2	1	4	7	1	4	6	–	1	–	4	7	10	1	–	4	45	–	14	77.7
No. thoracenteces	3	4	2	12	8	5	20	4	27	5	7	10	6	3	7	2	6	12	143	7.9
Days until first tap	5	4	13	2	1	14	4	26	1	1	1	1	10	16	2	11	1	2	108	6.0
F. B. present at time of clot	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	–	1	15	83.3
Week of decortication	10	3	7	4	5	5	5	9	7	5	2	8	2	4	2	7	11	4	100	5.5

B = Bullet wound; H = High explosive.

TABLE III. SUMMARY OF 13 CASUALTIES WITH EMPYEMA

	CASE														
	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL	AVERAGE (%)
Penetrating	H	H	H	–	H	B	H	H	H	–	–	H	H	10	76.9
Perforating	–	–	–	B	–	–	–	–	–	B	B	–	–	3	23.1
No. fractured ribs	–	1	1	5	2	–	1	–	–	4	3	1	–	8	61.5
F. B. present at onset of the empyema	1	1	1	1	1	–	1	?	1	–	–	–	–	7	53.8
Wound infected with draining sinus	–	1	1	–	1	–	1	–	–	–	–	–	–	4	30.8
Weeks following wound	4	3	6	6	7	3	8	3	6	4	8	–	–	–	5.2
Prevailing organism	?	Sa	Sa	Bp	?	?	Sa	?	Sa	?	?	Sa	Sa	–	–
Treatment	O	O	D	D	O	O	D	O	D	O	O	C	C	–	–
Evac. for convalescence	–	–	1	1	d		1	–	1	–	1	1	1	7	53.8
surgery	1	1	–	–	d	1	–	1	–	1	–	–	–	5	38.2

Sa = *Staphylococcus aureus;* Bp = *B. proteus;* ? = not recorded; D = decortication; O = open drainage; C = closed drainage; H = high explosive; B = bullet.

TABLE IV. SUMMARY OF THE 66 PATIENTS EVACUATED TO THE MAINLAND

Evacuated for cause not related to the chest wound		34
Evacuated because of the chest wound and its complications		32
For convalescence only (would be able to do duty within a few weeks)	18	
Observation for retainded metallic foreign bodies	7	
Chronic empyema	5	
Pulmonary tuberculosis	1	
Traumatic cyst of the lung	1	
	32	

TABLE V. SUMMARY OF THE COMPLICATIONS

COMPLICATIONS AND AREAS AFFECTED	NO.	%
Lungs and pleura		
Clotted hemothorax (large)	16	9.3
Empyema	13	7.6
Bronchopleural fistula		
Following decortications	7	4.1
Following removal of MFB	3	1.8
Atelectasis	2	1.2
Tuberculosis	1	0.6
Traumatic cyst of the lung	1	0.6
Persistent pleuritic friction rub	1	0.6
Heart and great vessels		
Tachycardia	3	1.8
Traumatic myocarditis	1	0.6
Aortic diastolic murmur	1	0.6
A-V aneurysm (rt. subclavian art.)	1	0.6
Liver		
Acute hepatitis	2	1.2
Multiple abscesses	1	0.6
Kidney		
Sulfadiazine crystal colic	1	0.6
Spinal cord		
Transection (partial)	1	0.6
Concussion	1	0.6
Thrombophlebitis	3	1.8
Decubitus ulcer	1	0.6

TABLE II. SUMMARY OF CASES TREATED BY DECORTICATION

	CASE																			
Wound	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	TOTAL	%
Penetrating	B	–	H	–	H	H	H	H	–	H	H	H	B	H	H	H	H	H	15	83.3
Perforating	–	B	–	B	–	–	–	–	B	–	–	–	–	–	–	–	–	–	3	16.7
Sucking	1	1	1	–	1	–	1	1	–	1	1	1	1	1	–	1	1	1	14	77.7
Pneumothorax	1	?	–	–	1	–	1	?	–	1	–	1	1	?	1	?	1	1	9	50.0
No. fractured ribs	2	–	–	2	–	–	–	1	5	–	–	1	1	–	–	–	1	–	7	38.9
Days of hemoptysis	2	1	4	7	1	4	6	–	1	–	4	7	10	1	–	4	45	–	14	77.7
No. thoracenteces	3	4	2	12	8	5	20	4	27	5	7	10	6	3	7	2	6	12	143	7.9
Days until first tap	5	4	13	2	1	14	4	26	1	1	1	1	10	16	2	11	1	2	108	6.0
F. B. present at time of clot	1	–	1	–	1	1	1	1	1	1	1	1	1	1	1	1	–	1	15	83.3
Week of decortication	10	3	7	4	5	5	5	9	7	5	2	8	2	4	2	7	11	4	100	5.5

B = Bullet wound; H = High explosive.

TRAUMATIC DIAPHRAGMATIC HERNIA

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DIAPHRAGMATIC hernias of traumatic origin have been seen with increasing frequency during the period of the war. Many of these have resulted from penetrating wounds and injuries; others have been caused by crushing injuries and automobile accidents, and a few have resulted from incidents causing a sudden increase in the intra-abdominal pressure. The purpose of this paper is the presentation of twenty-eight traumatic diaphragmatic hernias operated upon at Kennedy General Hospital during the past three years. Injuries of the diaphragm were associated with other injuries, and with few exceptions these injuries were repaired when the original operation was performed. Of the approximately 2,000 patients with chest wounds who were admitted to Kennedy General Hospital from January, 1944, to April, 1946, only sixteen had diaphragmatic hernias. The twelve others had diaphragmatic hernias resulting from injuries unrelated to a battle.

ETIOLOGIC FACTORS

Penetrating wounds due to machine gun, rifle, or pistol bullets caused twelve hernias. Shell fragments caused the defect in four, and in one patient the injury was the result of a stab wound. Automobile, truck, or jeep accidents caused the diaphragmatic injury in nine patients; one injury was the result of a fall, and another the result of jumping from a truck.

The diaphragmatic wounds were the result of either a penetration (seventeen) or rupture (eleven) of the structure. Much has been written about the contusion type of injury commonly seen in civilian practice and most often due to automobile accidents.

The embryology, development, anatomy, and location of anatomic diaphragmatic defects where hernias are prone to occur are described in the literature. We are unable to correlate anatomic weakness with the size and location of these hernias. (Diagram 1.) A small defect 1.5 cm. was found due to an automobile accident in one patient, while a 15 cm. defect was found in another patient who had fallen a short distance. Several small defects were the result of bullet wounds, but a very extensive diaphragmatic defect was the result of being subjected to machine-gun fire.

The diaphragmatic hernia occurred immediately in thirteen of the seventeen patients with penetrating injuries and in ten of the eleven contusion injuries. The absence of herniation after injury is shown in Figs. 3 and 5. A repair of the diaphragmatic injury was made at the original operation in six cases.

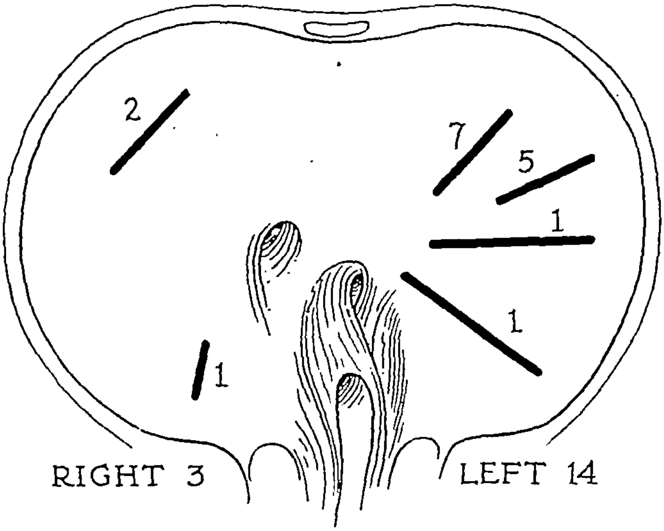
From the Chest Surgical Section, Memphis, Tennessee, Kennedy General Hospital.

Read at the Twenty-Sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30, and 31, 1946.

*Formerly Major, Medical Corps.

†Formerly Lieutenant Colonel, Medical Corps.

It is obvious that increased abdominal pressure as a result of strain may be the immediate cause of the herniation through small defects in the diaphragm that are the result of previous injury. Occasionally, the original injury was insignificant and no thoracotomy was necessary. In only five of our cases was the injured diaphragm repaired at the front. The others had wounds produced by bullet or shell fragments which were so small that no herniation occurred until prolonged strain, or a sudden strain, caused enlargement of the defect. In one instance this was strikingly demonstrated when a soldier who had had a penetrating chest wound thirteen months previously suddenly developed acute


LOCATION OF HERNIA

17 penetrating wounds

11 wounds due to contusions

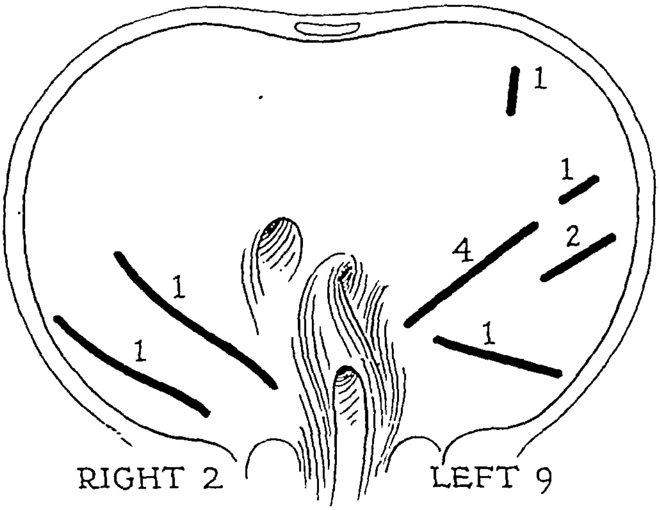


DIAGRAM 1.

TABLE I. ETIOLOGIC FACTORS

TYPE OF INJURY	NO.	TOTAL
Penetrating injuries		17
Bullet wounds	12	
Shell fragment wounds	4	
Stab wounds	1	
Nonpenetrating injuries		11
Automobile accidents	9	
Fall	2	
Total		28

TABLE II. HERNIATED ORGANS

ORGAN AND SITE OF HERNIA	NO.	TOTAL
Through right diaphragm		5
Liver	4	
Kidney	1	
Through left diaphragm		23
Stomach	2	
Stomach and omentum	2	
Stomach and spleen	1	
Stomach and liver	1	
Omentum	3	
Colon and omentum	4	
Stomach and colon	1	
Stomach, colon, small intestines, and omentum	3	
Stomach, colon, small intestines, liver, and omentum	2	
Stomach, colon, small intestines, spleen, and omentum (One associated with a pericardial tear)	2	
Stomach, colon, small intestines, omentum, spleen and kidney	1	
Colon, small intestines, omentum, and spleen	1	
Total		28

TABLE III. SYMPTOMS OF LEFT DIAPHRAGMATIC HERNIA (23 CASES)

TYPE OF HERNIATION	SYMPTOMS
Of sudden herniation of hollow viscus	Unconsciousness Nausea and vomiting Dyspnea Epigastric pain
Of chronic herniation of hollow viscus	Epigastric pains, especially after meals or when recumbent Indigestion Flatulence Dyspnea Bubbling sounds in chest
Herniation of solid viscus	Pain in chest

upper abdominal pain while carrying heavy sacks and was found to have almost complete herniation of his stomach into his chest (Fig. 7). Sudden acute symptoms were produced in another case by the soldier jumping from a truck. In this instance his colon herniated through a defect only 1½ cm. in diameter and by the time he was admitted to this hospital gangrene of the bowel had developed (Fig. 6). He made an uneventful recovery following resection of the colon and repair of the hernia. Three other patients who were known to have hernias of several months' duration developed acute obstruction while under observation here or at other hospitals. Emergency operation was successfully performed in each case.

Our first diaphragmatic hernia was in a man who had been shot through the right chest by a bullet in May, 1943. When seen in June he was found to be well and roentgenograms of the chest were not significantly abnormal, so that he was returned to limited duty. One year later he began having pains in his right lower chest and a rounded mass overlying the diaphragm was seen on the roentgenogram. Exploratory thoracotomy was performed and he was found to have a hernia of a portion of the right lobe of his liver through the diaphragm. X-rays of a similar case are shown in Fig. 3. These cases are cited because it is believed that many similar ones will arise during the course of the next few years.

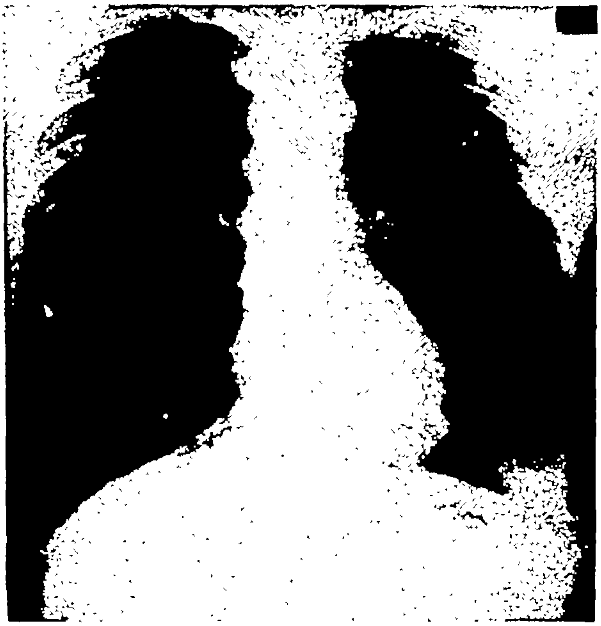


Fig. 14.—P. D. R. An asymptomatic lesion found on routine Army discharge film. The soldier was wounded at Pearl Harbor and had done duty for three years. The preoperative diagnosis was tumor or encapsulated hematoma.

SYMPTOMATOLOGY

Herniation of solid viscera was associated with rather vague pain in the lower chest. When hollow viscera were herniated, symptoms of various types and severity developed. In eleven of these due to battle wounds associated with other injuries, the symptoms of the hernia were at first frequently masked. Later, epigastric pain, especially after meals and when the patient was recumbent, flatulence, indigestion, and dyspnea were noted. Several patients could hear and feel gurgling sounds in the chest.

In the instances of sudden herniation of a hollow viscus, the symptoms were more dramatic. In two instances unconsciousness occurred which could not be accounted for by the associated injuries. Dyspnea appeared in those cases in which the herniation caused considerable collapse of the lung. The other symptoms, pain, nausea, and vomiting, were dependent upon the extent of the herniation and the amount of obstruction produced.

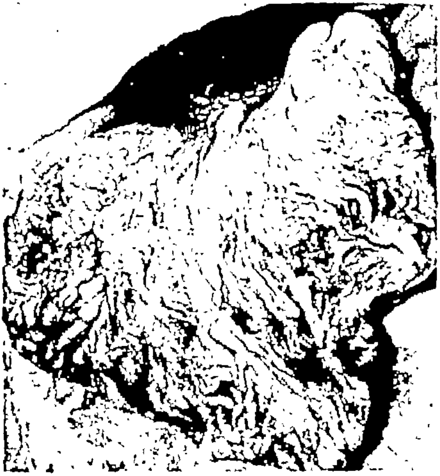


Fig. 1B.—Photograph at operation showing the herniated omentum spread over chest wall.

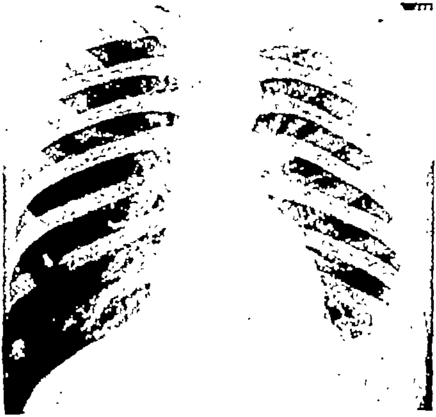


Fig. 1C.—Postoperative roentgenogram.

Exploration of a draining chest-wall sinus revealed an asymptomatic herniation of a portion of the omentum in two recurrences that followed repair of a diaphragmatic injury overseas.

TREATMENT

Operative repair was successfully carried out in all cases. There was an immediate recurrence in one case which was promptly recognized and successfully repaired five months later. In all instances a transthoracic approach was used and, except in one case, was done under endotracheal anesthesia. The one exception was the case in which a preoperative diagnosis of encysted fluid was made and at operation a hernia of a portion of the right lobe of the liver was found.

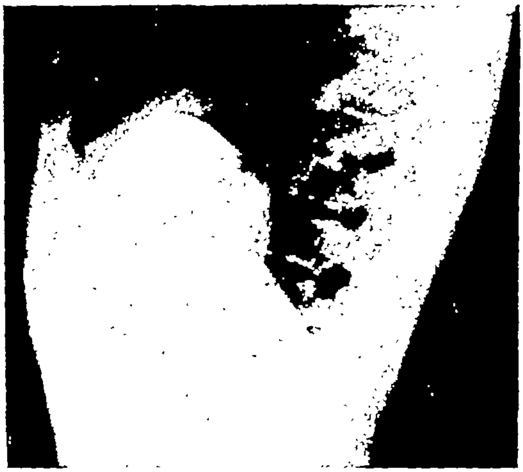


Fig. 24.—C. J. F. Herniation of a cystic kidney following an automobile accident ten years previously.

The transthoracic approach was usually made through the bed of the eighth or ninth rib with the patient lying on his side. The excellent exposure so easily obtained by this route kept us from considering the abdominal approach. In a number of instances the herniated structures extended up to the dome of the thorax, and in such cases the adhesions present would have been handled only with the greatest of difficulty through an abdominal approach.

Occasionally, when the hernia was first exposed, it seemed that not enough of the diaphragm remained to allow adequate closure, but in every case after careful dissection, sufficient diaphragm was developed to permit satisfactory closure. In several instances it was necessary to dissect the extension of the iaphragm into the transversalis muscle to obtain closure without tension. Two ows of interrupted silk sutures were used, the second burying the first. When he diaphragm was detached from the chest wall, mattress sutures through the hest wall tied over tubes were employed to obtain a secure closure. This was ollowed by interrupted intrapleural sutures. In the first half of the series of ases the phrenic nerve was not always crushed unless the line of the defect was uch that contraction of the diaphragmatic fibers caused a pull on the suture ne. Following the immediate recurrence of one hernia after excessive

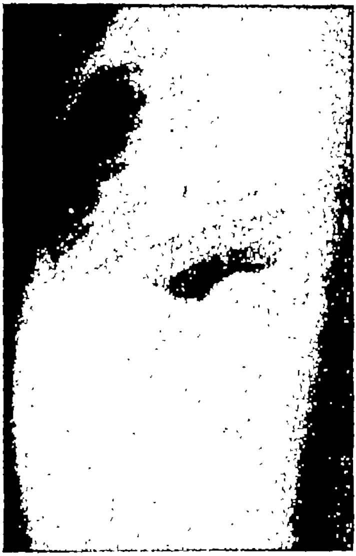


Fig. 2*B*.—One year after first repair elsewhere.

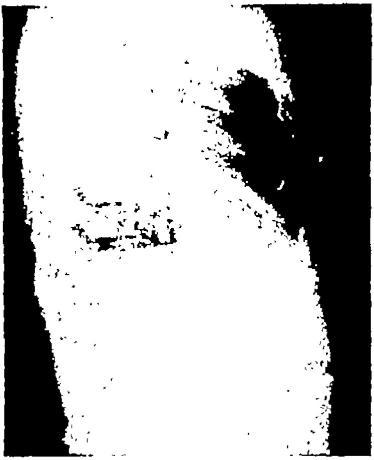


Fig. 2*C*.—Roentgenogram following nephrectomy and second repair of the hernia. Mattress sutures of tantalum wire were placed through the diaphragm and the chest wall and tied over rubber tubing because the diaphragm had been detached from the chest wall.

diaphragm and was asymptomatic. The operations in such patients were done for other associated conditions. In four cases in which the liver was the herniating organ, only a presumptive preoperative diagnosis of diaphragmatic hernia was possible. Two of these have already been referred to as examples of an *apparently slight injury to the diaphragm which later, after more than a year,* allowed herniation of the liver. In one case, the incarceration of the stomach resulted in progressive distension until the entire left pleural space was filled. However, there was no impairment of the blood supply. The left lung was completely atelectatic. After enlarging the defect, it was possible to express the air from the stomach through the rubber tube inserted through the nose prior to operation. Separation of adhesions was then possible, allowing reduction of the hernia.

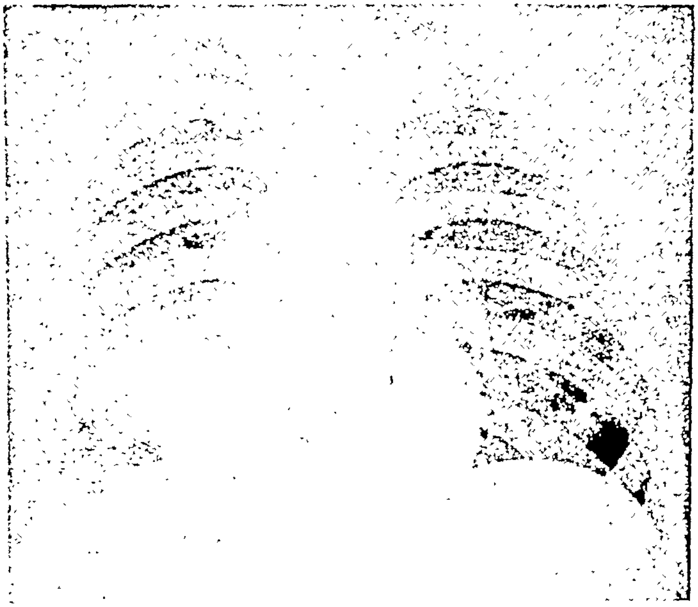


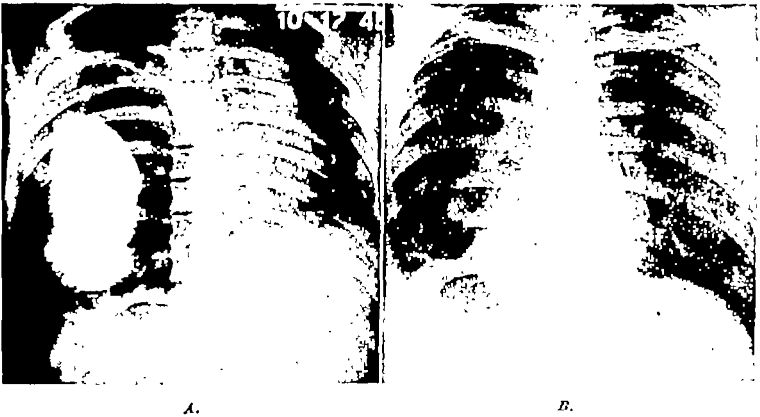
Fig. 6.—W. N. Roentgenogram of chest twelve hours following a jump from a truck. Herniation of the colon had occurred through a defect 1.5 cm. long. Approximately 15 cm. *of gangrenous colon was resected and a double barrelled colostomy performed after the chest* was closed with intercostal tube drainage connected to a water trap. Recovery from this operation and closure of colostomy was uneventful.

In only two of the entire series of hernias was a definite sac demonstrable. There often was a membrane covering a part of the herniated structure, but it was not complete. Adhesions between all structures were always present, but varied in extent and character. At times it was impossible to separate the herniated structures from the lung without some damage to it. The size of the opening in the diaphragm varied greatly from one of 1.5 cm. in diameter to one that involved the entire dome and extended into the pericardium.

The dome of the left diaphragm was the site most commonly involved, herniation through this area occurring in twelve cases. (Diagram 1.) The other sites were: right dome, three; right posteriorly, two; left posteriorly, two; left anterolaterally, two; left laterally, seven. The contusion defects are seen to be more peripheral *and the penetrating defects more centrally located* on the diaphragm.

Herniation of the colon through a defect 1.5 cm. long was followed by gangrene of the colon. The gangrenous portion of bowel was removed by cutting between clamps, and the two ends of the bowel covered with rubber glove and pushed out a left rectus incision. The defect was then repaired, the pleural cavity irrigated with saline, penicillin instilled, the lung expanded, and the pleural space drained by an intercostal tube connected to a water trap. A double-barrelled colostomy was then performed.

One large hernia was associated with an 8 cm. pericardial tear; another with herniation of the kidney, spleen, stomach, jejunum, ileum, colon, and omentum. These structures were densely adherent and completely covered the lateral portion of the diaphragm. A constricting ring defect around a herniated stomach was found in one case (Fig. 4). Had this progressed, it could have led to ischemic changes that would have been followed by perforation.



A. *B.*

Fig. 7.—H. F. *A*, Regional Hospital roentgenogram with the patient supine showing a greatly distended stomach partially filled with barium occupying the left pleural cavity. This Prisoner of War was injured in France in 1944, and had been working in this country for a year. The herniation followed carrying heavy sacks. *B*, postoperative roentgenogram. Recovery was uneventful.

In one instance, following a previous repair elsewhere, the diaphragm had been severed from its attachments to the posterior chest wall. A hydronephrotic, congenital, bifid kidney herniated through this defect. In this patient it was necessary to mobilize and remove the kidney before the diaphragm was repaired. Mattress sutures were passed through the diaphragm and chest wall to obtain a secure closure. Additional interrupted sutures were also employed between the diaphragm and intercostal muscles. The lung was collapsed to varying degrees, but in all instances re-expanded without difficulty. The length of time during which the collapse had been present seemed to make little difference in the ease with which re-expansion occurred. Although the chest was aspirated in two patients with herniated stomach and intestines, under the mistaken impression of pleural fluid, no harm resulted. At the time of the repair of the hernia, no evidence of infection or other damage was found.

COMPLICATIONS

In one instance there was a rupture of the sutured diaphragm during the first day after operation. This was apparently due to the violent contractions of the unparalyzed diaphragm produced by vigorous use of intratracheal suction during the first few postoperative hours. The condition was promptly recognized and corrected. After this the diaphragm was paralyzed in each case except with small defects on the right side. In one patient in which the lung was damaged while separating it from the herniated liver, a pneumothorax developed which persisted for a short time. Pleural effusion of transient nature occurred three times and in one patient an empyema developed. This patient had previously had an empyema complicating the original injury that required treatment before the hernia could be repaired.

SUMMARY

1. An analysis of twenty-eight traumatic diaphragmatic hernias that were repaired at the Kennedy General Hospital during the period from Jan. 1, 1944, to April 1, 1946, is presented. Sixteen of these were due to war wounds of the diaphragm, nine resulted from automobile accidents, two from falls, and one from a stab wound.
2. The right diaphragm was the site of hernia in five cases and the left in twenty-three.
3. Obstructive symptoms necessitated emergency operations in five cases.
4. Roentgenographic studies were diagnostic when hollow viscera were involved.
5. The diagnosis was not made until thoracotomy was performed in eight cases. These were instances in which the liver or omentum were the herniating structures.
6. Repair of the hernia was accomplished in every case through a transthoracic approach.
7. Endotracheal ether anesthesia was used in each instance except one.
8. The diaphragmatic repair was accomplished by means of two rows of interrupted silk sutures.
9. Paralysis of the diaphragm was induced in ten cases at the time of operation and was made a routine procedure.
10. Although excellent results were obtained in all patients before their discharge from the hospital, one immediate postoperative recurrence developed that was repaired later. Transient pleural effusion occurred in three patients, transient pneumothorax in one, and an empyema in another.

CONCLUSION

Apparent slight injuries to the diaphragm may give rise to herniation at a later date. The medical profession should keep this fact in mind in dealing with veterans who have had wounds of their chest and with others who have had previous episodes of trauma, such as an automobile accident or a fall. Hernial repair was obtained in all cases presented. The transthoracic approach under endotracheal anesthesia allows optimum exposure.

EXTRAPLEURAL PNEUMONOLYSIS WITH LUCITE PLOMBAGE

A Preliminary Report

David A. Wilson, M.D.
Greenville, S. C.

INTRODUCTION

During the past fifteen years we have seen a gradual improvement in the surgical treatment of pulmonary tuberculosis. There has been a definite lowering of the mortality and morbidity rates and a general improvement in the patient's prospect for the future. This advancement has been the result of improved anesthesia, operating, and operating room techniques, and the liberal use of blood, plasma, and prophylactic chemotherapy. The addition of pulmonary resection to the surgical management has been another step forward. Many who previously were considered hopeless are now given a favorable prognosis.

Despite this optimistic outlook, one still sees a great number of patients with stabilized pulmonary tuberculosis who cannot be managed by any of the present-day surgical methods of treatment; that is, patients with bilateral apical cavities, patients with low vital capacity, and patients of advanced age. For these patients we are constantly seeking new methods of treatment.

An approach to the solution of the problem has been extrapleural pneumonolysis and plombage. The advantages of this procedure have been pointed out by previous workers. It permits the selective collapse of the diseased lung and preserves the function of good lung tissue. It stabilizes the mediastinum and lessens the danger of bronchogenic spread. It preserves the normal chest structure.

The deterring factor which has prevented the successful utilization of this operation has been the lack of a solid material which can be molded to fit varying sized pockets and which can be left in the chest permanently without danger of harmful effects.

An attempt toward the experimental solution of this problem was begun in the fall of 1943, utilizing a plastic resin, methyl methacrylate, more commonly known by its trade names as Lucite, Plexiglass, Crystallite, Vitarilic, and others. This paper is a summary of the experimental studies and a preliminary report of the first fifteen patients in which this material has been used to maintain a surgical collapse of the lung for the treatment of pulmonary tuberculosis. The first patient was operated upon in July, 1945, and the fifteenth in December, 1945.

HISTORICAL

Extrapleural pneumonolysis is one of the oldest operations in thoracic surgery. It was introduced by Tuffier in 1891.

From a surgical standpoint it is an attractive procedure utilizing skill and judgment. From a theoretical standpoint the operation is sound in that relaxation of the lung in a

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Read (by title) at the Twenty-Sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30, and 31, 1946.

limited area or in all directions can be secured by extrapleural freeing of the lung." From a practical standpoint it has been most disappointing. The criticism has arisen not so much from the operative procedure as from the material which has been used to maintain the collapse.

Fat taken from the patient's subcutaneous tissue was first utilized by Tuffier in 1910. In his series of eleven cases there was only one cure, and there were four deaths.

Baer, in 1913, employed a paraffin mixture which hardened at body temperature and met the mechanical requirements better than fat. This material was used extensively in European hospitals by Sauerbruch, Nissen, and co-workers. In this country the operation never became popular, because complications which were difficult to manage frequently attended its use. Necrosis of thin-walled cavities and penetration of the free pleural cavity occurred. Severe infections were common.

Head as late as 1937, advocated the paraffin pack as a preliminary to thoracoplasty in the management of large apical cavities. He observed a higher percentage of favorable results than when thoracoplasty was performed as the initial operation. He attributed this fact to the lessened danger of contralateral spread as a result of diminution in size of the cavity and stabilization of the mediastinum prior to thoracoplasty. Twenty-four of the thirty-one patients in which this type of management was used had conversion of their sputum, three were improved, two were made worse, and two died. Perforation of the paraffin into the lung occurred in four patients.

Casper, Sauerbruch, Schlange, and Matson used plain gauze to fill the extrapleural space. In a preliminary report in 1938, Matson reported eighty-one patients in whom gauze had been used to maintain an extrapleural collapse. Conversion of sputum was secured in fifty-four patients. Only fifteen were considered clinically well with the pack removed. Infection occurred in eighteen patients, necessitating early removal of the gauze. There were four deaths, none directly attributed to the operation.

Archibald, Alexander, Churchill, Goffaerts and DeWinther, Sebrechts, and Shivers have advocated filling an extrapleural pocket with pectoral muscles detached from the chest wall and humerous. Archibald and Butler, Skinner, Douglas, and Merkel combined muscle packing with thoracoplasty. The disadvantages of these procedures were the increased operating time, the limited amount of muscle available for use, and the tendency of the muscles to atrophy.

The maintenance of an extrapleural space by means of air refills was first attributed to Mayer in 1913. In 1920, Rieckenberg and, in 1921, Jessen reported a small series of successful cases. In 1932, Jachia and Sebestyen advocated combining an extrapleural pneumothorax with an unsuccessful intrapleural pneumothorax. Between 1933 and 1938 an increasing number of cases was reported by Belsey, Graf, Nissen, Michelsson, Overholt and Tubbs, Schmidt, and Zorini. In 1939 Schmidt and his co-workers[4, 9, 24, 32] reported 544 cases with a good percentage of favorable results.

The use of extrapleural pneumothorax gained widespread popularity in this country between 1938 and 1940. This popularity, however, was short-lived. It soon became evident that air was not an ideal material to maintain an extrapleural collapse of the lung. The postoperative management was difficult. Refills were necessary at frequent intervals, and re-expansion of the lung failed to occur when treatment was discontinued. The space then had to be obliterated by means of a thoracoplasty or by filling with oil.

In 1940 Dolley, Jones, and Skillen reviewed the results of treatment of over 2,277 patients from twenty-seven clinics where extrapleural pneumothorax had been in use for more than two years. The results varied with the extent of the disease of the patients selected for operation. Conversion of the sputum was secured in only 53 per cent of the patients, and 11 per cent were dead. There was a high incidence of infection.

EXPERIMENTAL STUDIES

Methyl methacrylate is a plastic manufactured from acetone, hydrogen cyanide, and methyl alcohol in the presence of sulphuric acid. The polymerized product is marketed in a clear solid form which softens at 105° C. and can be molded easily into any desired shape. It is light in weight, has a tensile strength of from 6,000 to 9,000 lb. per square inch, and is not affected by weak acids or alkalies. It absorbs a negligible amount of water.

The use of methyl methacrylate in experimental animals to repair skull defects was first reported by Kleinschmidt in January, 1940. Prior to this time it had been used extensively in dental prosthesis and had been shown to be nonirritating when left in contact with mucous membrane for a long period of time.

In our studies[31] the methyl methacrylate in the form of small balls was inserted into the pleural cavity of thirty rats and into the extrapleural space of ten dogs. The animals were carefully observed, and x-rays of the chest were taken at frequent intervals. Autopsy was performed ten days to eight months after operation, and the tissues studied histologically.

The material was well tolerated by all of the experimental animals. X-rays revealed no excessive accumulation of fluid around the implants nor pneumonitis in the adjacent lung tissue. Empyema occurred in two of the rats.

The tissue reaction around the balls in the extrapleural space was similar to that observed by Kleinschmidt. During the first few days following operation, the implants were surrounded by a small amount of serum which rapidly clotted and became organized into a dense layer of hyaline connective tissue. Numerous eosinophiles were observed in the connective tissue during the first few weeks, but there were no foreign-body giant cells, even after eight months.

When implanted directly into the pleural cavity, the methyl methacrylate produced little effusion. In ten of the rats the pleura remained intact, and the methyl methacrylate balls were still free in the pleural cavity several months after operation. Histologic studies revealed some thickening of the pleura and infiltration of eosinophiles into the submesothelial region. The compressed lung showed varying degrees of atelectasis.

CLINICAL STUDIES

In the beginning of this clinical work the author was convinced by the physical and chemical properties and from the animal experiments that methyl methacrylate fulfilled the qualifications of an ideal plombage material. It is inexpensive and readily available.* It can be molded into any desired shape prior to operation. It is of such light weight that a large quantity can be introduced into an extrapleural pocket without danger of penetrating the free pleural cavity or lung.

It is insoluble in the tissues and not subject to chemical change. It is nonirritating and causes no undesirable foreign-body reaction. It offers little resistance to x-rays and does not interfere with interpretation of chest films.

Since varying sized pockets were to be filled through relatively small incisions, methyl methacrylate in the form of a small ball was chosen as being most suitable for our purposes. As no commercial source was available at that time, these balls had to be manufactured in our own laboratory.

Two types were designed for clinical use, a solid ball of ¾ inch diameter and a hollow ball of one inch diameter. The solid balls weigh 4.5 Gm. each. They can be sterilized by boiling and do not interfere with interpretation of the chest x-rays. The hollow balls weigh 3 Gm. each and must be sterilized chemically. In the x-ray they appear as regular, circular shadows with a center of decreased density. This makes the x-ray differentiation from a pulmonary cavity difficult on plain films; however, they can be distinguished easily on laminographic films. In spite of these relative disadvantages, the hollow balls have proved most applicable to clinical use due to their light weight.

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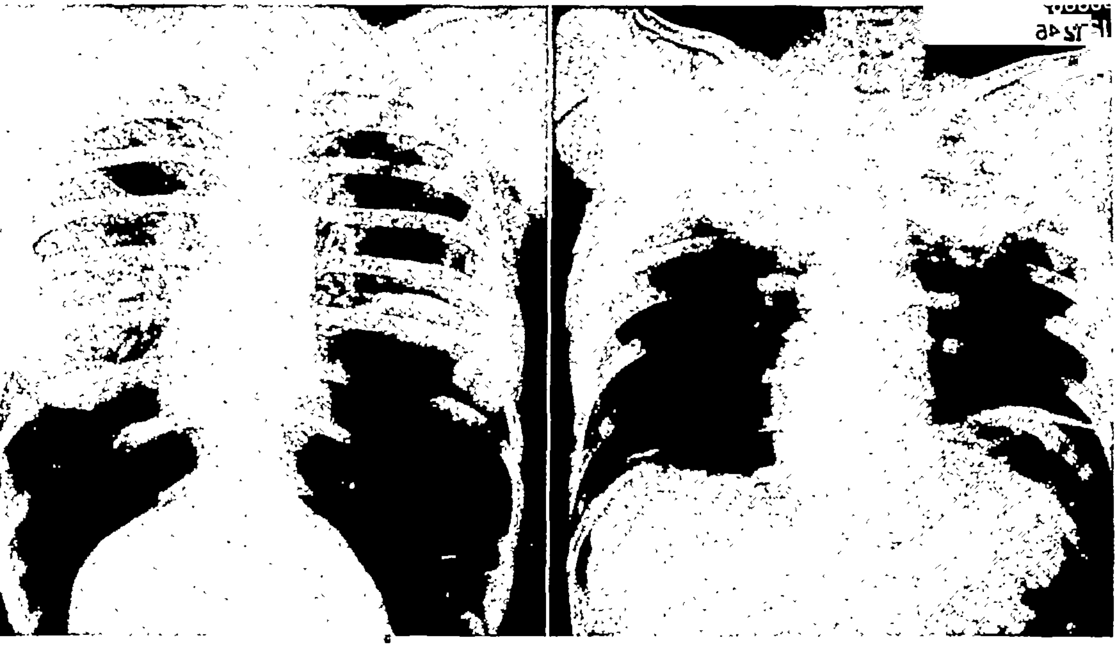
*The methyl methacrylate balls are now being manufactured by Nichols Products Company, 325 West Main Street, Moorestown, N. J.

The methyl methacrylate was first made into the shape of half spheres. These were stored in a 1:1,000 aqueous solution of Zephiran Chloride. Forty-eight hours prior to operation the half-spheres were removed from the zephiran solution under sterile precautions, dried, and under bactericidal radiation sealed together, using ethylene dichloride as the softening agent. This technique insured sterility of the air within the ball as well as the ball itself. After a few minutes during which the seal was allowed to dry, the balls were again immersed in the zephiran chloride solution to remain until used.

The average number of balls used per person was thirty. The smallest number used was fifteen, and the largest number was sixty.



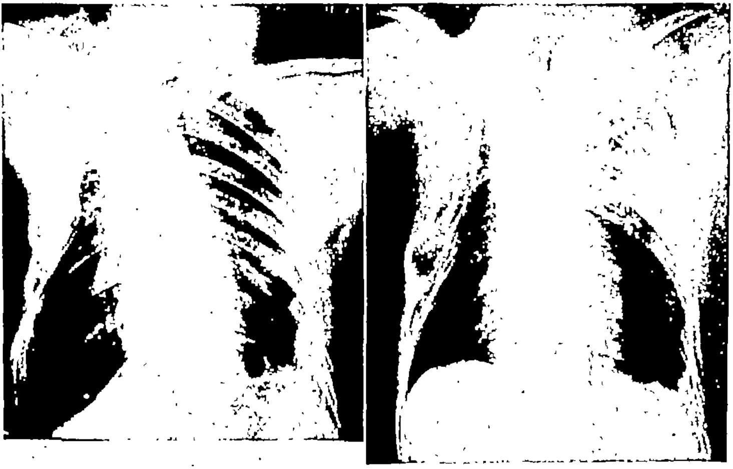
A. *B.*

Fig. 1.—*A*, X-ray of chest of patient (Case 11) showing bilateral apical cavities. *B*, After bilateral apicolysis.

In the selection of patients for operation no hard and fast rules have been established. The indications will, undoubtedly, vary with the experience gained by the clinical use of this material. All of the patients had been under sanatorium care and had shown some resistance to the disease process; therefore, recent spread did not constitute the same contraindication as for thoracoplasty. All of the patients had had pneumothorax attempted, and all had been bronchoscoped to rule out stenosis of the bronchus.

In the early phase of this clinical work the author was primarily concerned with the treatment of those so-called good chronic patients in whom thoracoplasty was contraindicated because of their low vital capacity, advanced age, or bilateral cavities, and with the treatment of those patients who had had an unsuccessful thoracoplasty. As experience has been gained in the use of the methyl methacrylate balls, the clinical application has been broadened to include borderline patients who, ordinarily, might have been considered suitable for thoracoplasty.

In twelve of the fifteen patients extrapleural pneumonolysis was performed in the apical region through an anterior incision. Preoperatively, the patient is given 0.1 Gm. of sodium pentobarbital and 10 mg. of morphine. The skin is infiltrated with 2 per cent solution of procaine. The incision is made parallel to and overlying the second rib and cartilage. The intercostal nerves are blocked with 2 per cent procaine, and a 4-inch segment of rib and cartilage resected by an aperiosteal dissection. The resected rib segment is carefully saved. An incision is made through the posterior periosteum, and the extrapleural space is carefully developed by blunt dissection. Special instruments are not necessary for the successful completion of this stage of the operation. Finger dissection first, then dissection with a small sponge on a clamp as the space is enlarged, is much safer than instrumental dissection. Freeing of the mediastinal pleura is usually accomplished without difficulty. Dense adhesions attached to the apex or lateral chest wall are best completely isolated and divided by sharp dissection close to their attachment to the rib, or more safely by removal of the adjacent periosteum. If isolated adhesions are so densely adherent to major vessels or nerves that they make division seem unwise, they may be left undivided without necessarily interfering with the successful completion of the operation, since compression can be secured on all sides by packing around the isolated segment of the lung. Local anesthesia is rarely required after the extrapleural space is entered. The patient experiences little discomfort except for some mild paroxysmal coughing when the mediastinal pleura is freed.



A. *B.*

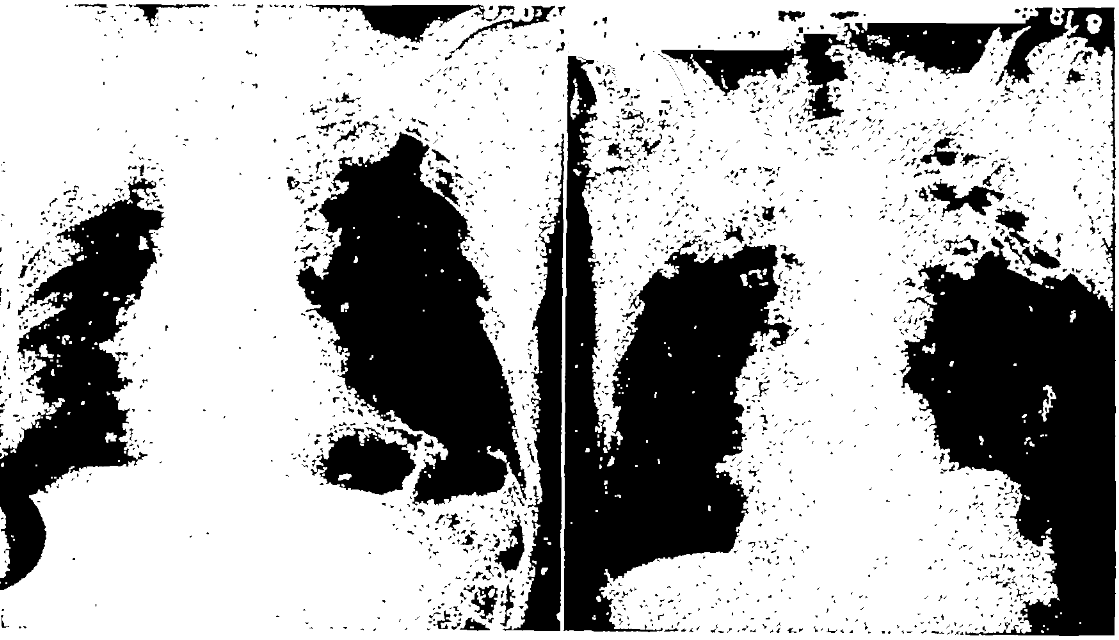
Fig. 2.—*A*, X-ray of chest of patient (Case 9), showing thoracoplasty on right side and cavity in the left apex. *B*, Postoperative x-ray of the same patient.

When the dissection has proceeded to the desired extent, the space is filled with methyl methacrylate balls. The desired degree of compression can be secured by having the patient expire while filling the pocket without tension. The balls are held within the extrapleural space by suturing the segment of rib into its original position and approximating the periosteum around it. One hundred thousand units of penicillin are injected into the extrapleural space, and closure is performed. The pectoral muscles are carefully reapproximated and sutured to the periosteum of the rib to prevent elevation of the incision by the fluid which accumulates in the extrapleural space postoperatively.

Eight of the patients on whom apicolysis has been performed had bilateral pulmonary involvement.

Two patients (Cases 11 and 14) had cavities in both apices. Bilateral apicolysis and packing with methyl methacrylate balls was performed in stages, two and three weeks apart. One patient has had a negative sputum since operation. (Fig. 1.)

Two patients (Cases 5 and 9) had apical cavities with a contralateral thoracoplasty. Both withstood apicolysis successfully. One patient complained of dyspnea for several weeks following operation, but this has gradually disappeared. His weight and general condition have improved, and his sputum is now negative. Sputum in the other patient has diminished greatly but is still positive. (Fig. 2.)



A. *B.*

Fig. 3.—*A*, X-ray of chest of patient (Case 4) showing large thin-walled cavity in the left apex and infiltration in right apex. *B*, Postoperative x-ray showing collapse of the left apex with hollow methyl methacrylate balls.

Two patients (Cases 4 and 13) had cavities in the apex of one lung with dense infiltration and scarring in the apex of the other lung. Apicolysis and packing with methyl methacrylate balls was performed on the side of the cavity in both patients. One patient has had a negative sputum since operation. (Fig. 3.) This patient had a 4 cm. thin-walled cavity which at the time of operation could be depressed with ease by the operator. A ball was placed in this depression at operation maintaining the sides of the cavity in apposition. The other patient has had only one positive sputum in four examinations since operation.

A 31-year-old white woman (Case 6) was admitted for extrapleural apicolysis because low vital capacity contraindicated thoracoplasty. She gave a history of pulmonary tuberculosis of eleven years' duration. Pneumothorax, phrenic crush, and pneumoperitoneum had been tried without success. Her vital capacity on admission was 900 c.c. Extrapleural apicolysis was performed without difficulty. The entire apex was stripped free from the chest wall and packed against the mediastinum with twenty-two hollow balls. She complained of some increased dyspnea immediately following operation, and quantity of sputum was greatly increased. At the present time her general condition is greatly improved. There is little or no sputum. The vital capacity is 750 c.c.

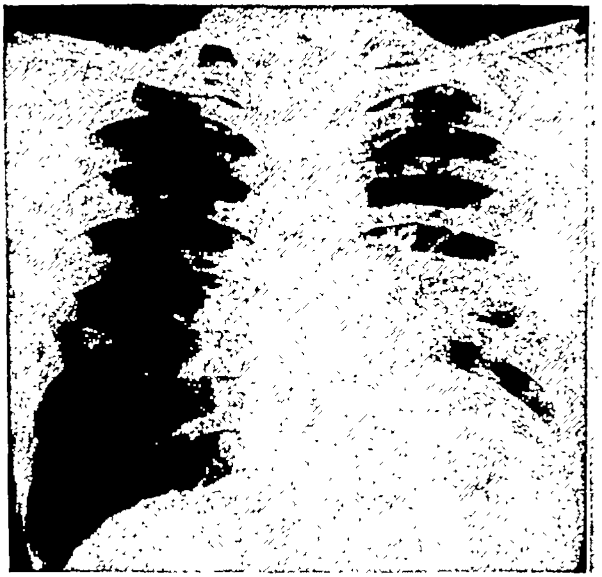
A 50-year-old white man (Case 7) was admitted to the hospital for treatment of a cavity in the left lower lobe near the costovertebral angle. (*Fig.* 4.) *He gave a history of* asthma of thirty years' duration and pulmonary tuberculosis of six years' duration. Pneumothorax, phrenic crush, and pneumoperitoneum had been tried without successful closure of the cavity. Vital capacity was 2,550 c.c. prior to operation. Extrapleural pneumonolysis was performed through an incision overlying the ninth *rib in the posterior axillary line.* Dissection was found to be easier in this area than in the apex of other patients due to the presence of fat located in the extrapleural space. The pleura in the region of the cavity was greatly thickened. After the entire lower lobe had been mobilized, the space was filled with sixty hollow balls. The segment of rib was resutured into place in the usual manner, and the incision closed. The postoperative course was uneventful. He was discharged to return to the sanatorium on the tenth postoperative day. The vital capacity at that time was 1,975 c.c. At present the patient has no cough and only a small amount of early morning sputum which has been intermittently positive for acid-fast organisms since operation.

The average age of the patients operated upon was 42. The youngest was 25, and the oldest 59 years of age. This latter patient (Case 15) was admitted with a history of pulmonary tuberculosis of two years' duration. She had a 4 cm. cavity in the right apex which had been treated unsuccessfully with pneumothorax, phrenic crush, and pneumoperitoneum. Extrapleural apicolysis with mobilization of the entire apex and packing with twenty-seven hollow balls was performed on December 20, 1945. Her sputum is still positive for acid-fast organisms but has diminished from one-half cup per day to little or none.

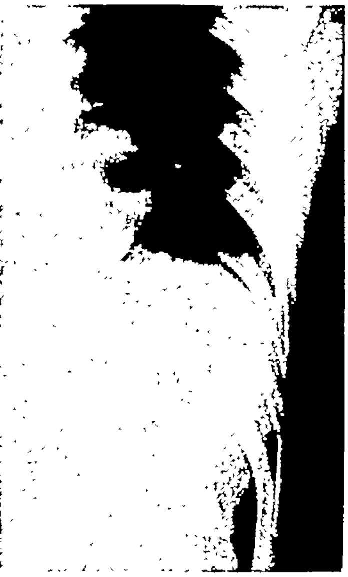
Four of the patients on whom apicolysis and packing with methyl methacrylate balls was performed had had a thoracoplasty on the side of operation. One patient (Case 1) had had a bilateral thoracoplasty, and three of the patients (cases 2, 3, and 12) had had an extrafascial apicolysis performed at the time of thoracoplasty. Dissection in these cases was only slightly more difficult than in those patients on whom no previous operation had been performed. In only one case did extrapleural dissection prove too difficult through an anterior approach and have to be abandoned. This patient (Case 8) was later dealt with through a posterior approach, combining packing with a modified two-stage revision thoracoplasty.

Patients with uncollapsed cavities beneath a thoracoplasty constitute a group in which this procedure would appear to be indicated instead of a revision thoracoplasty. Many of these patients have cavities which are located in the costovertebral angle or anteriorly where successful closure by complete costectomy is unlikely. Extrapleural apicolysis and packing offers these patients a single-stage operation which can be performed under local anesthesia with little or no shock. It permits localized compression of the involved area of the lung.

During recent years more and more attention has been called to the need for some method to maintain a collapse of the apex between the stages of a thoracoplasty. The experience of many surgeons has been the occurrence of a negative sputum immediately after the first stage with a return to positive before the second stage. The extrafascial apicolysis, which is frequently performed with the first stage, creates a pocket similar to that developed by

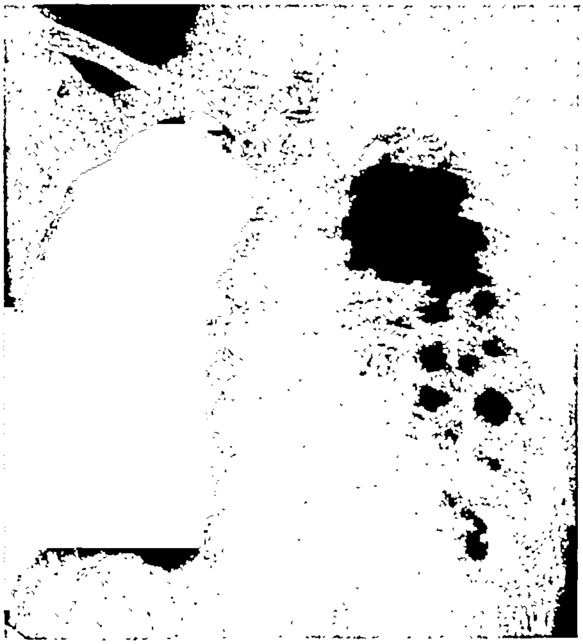


A.



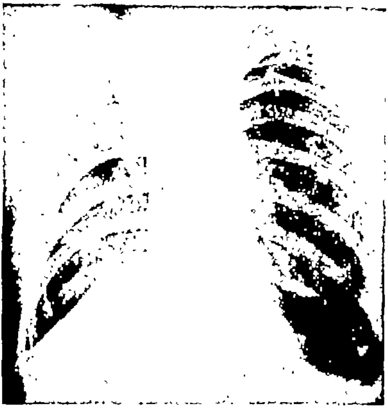
B.

Fig. 4*A*.—X-ray of the chest of patient (Case 7).
Fig. 4*B*.—Cavity is demonstrated by laminographic x-rays 5 cm. from posterior chest wall.



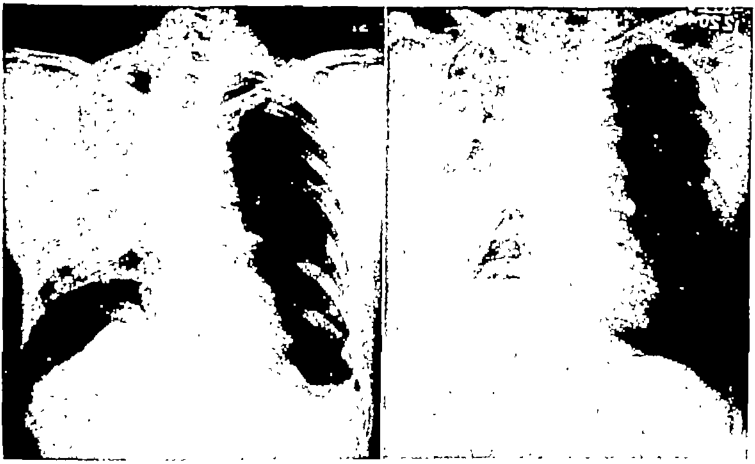
C.

Fig. 4*C*.—Postoperative x-ray showing collapse of left lower lobe by sixty hollow methyl methacrylate balls.



A.

Fig. 5A.—X-ray of chest of patient (Case 10) before operation.



B.

C.

Fig. 5B.—X-ray of same patient after modified first stage thoracoplasty, apicolysis, and packing with hollow methyl methacrylate balls. The third and fourth ribs have been removed.

Fig. 5C.—X-ray of same patient after second stage thoracoplasty.

extrapleural apicolysis. This space contains air and fluid immediately after operation, and re-expansion occurs rapidly as the air is absorbed. The filling of this space with a rigid material, such as methyl methacrylate, would not only prevent re-expansion of the apex but would also prevent mediastinal shifting and lessen the danger of bronchogenic spread.

One patient (Case 10), a 42-year-old white man, has been operated upon with these considerations in mind. (Fig. 5.) This patient was first admitted to the Eastern North Carolina Sanatorium in September, 1944, with far-advanced bilateral tuberculosis. Pneumothorax was instituted on the right but had to be discontinued due to adhesions and the formation of a pleural effusion. A right phrenic crush was performed in September, 1944, and in January, 1945, pneumothorax was started on the left side. At the time of admission to Duke Hospital in November, 1945, fluoroscopy of the chest revealed multiple cavities in the right apex, paralysis of the right side of the diaphragm, and a successful pneumothorax on the left side. On Nov. 30, 1945, a modified first-stage thoracoplasty was performed on the right side. The third and fourth ribs were removed, and an apicolysis was performed. The first and second ribs were left in place to protect the brachial plexus and vessels. The pocket was then filled with forty-eight hollow methyl methacrylate balls holding the apex of the lung below the fifth rib posteriorly. Closure of the wound was performed in the usual manner with the balls being held in position by the scapula and the weight of the shoulder. He complained of moderate pain but had no difficulty in breathing or raising sputum. The sputum remained positive for acid-fast organisms, and on December 18 a second-stage procedure was performed with removal of the fifth, sixth, and seventh ribs and transverse processes. The balls maintaining the apical collapse were left undisturbed. His postoperative course was uneventful. Sputum has been negative since the second stage. Pneumothorax is still being maintained on the left side. The vital capacity was reduced from 2,300 c.c. to 1,400 c.c.

POSTOPERATIVE COURSE AND COMPLICATIONS

The postoperative management of the patients following packing with methyl methacrylate balls was relatively easy. All of the patients complained of a moderate amount of pain and a feeling of pressure in the operative site for several days. Two of the patients noticed the clicking together of the balls in the chest, and one complained of difficulty in swallowing. These symptoms completely disappeared within the first two or three weeks.

The reduction of vital capacity varied with the extent of the pneumonolysis and the individual patient. The average reduction was 400 c.c. Two of the patients complained of marked dyspnea. One patient (Case 6), with a preoperative vital capacity of 900 c.c., has gradually improved and is now quite comfortable with a vital capacity of 750 c.c. The second patient (Case 3), a 47-year-old white man with a complicating asthma, died suddenly on the eighth postoperative day. Vital capacity before operation was 1,100 c.c. On the sixth postoperative day the vital capacity was 800 c.c. Autopsy revealed marked dilatation of the right side of the heart and diffuse scarring of both lungs. Death was attributed to cardiac failure as a result of diminished pulmonary circulatory bed.

The average maximum postoperative temperature elevation was 38° C. usually occurring on the second or third postoperative day and returning to normal by the seventh postoperative day. Two patients had temperature elevations of 39° C., with a gradual decline to normal by the tenth postoperative day. Four patients had a temperature of less than 37.5° C. postoperatively.

One patient (Case 2) developed a small superficial hematoma which was drained by spreading the incision and which healed promptly. There were no infections in this series of patients.

All patients were operated upon in rooms equipped with bactericidal ultraviolet radiation[12] and were given penicillin postoperatively, for ten days. The author feels that these precautions contributed to the benign postoperative course of the patients and the absence of infections.

Excessive accumulation of fluid around the balls postoperatively was not a problem. In only one patient (Case 2) was the accumulation of fluid beneath the incision sufficient to warrant aspiration. This complication was avoided in subsequent cases by a careful approximation of the tissue planes during closure.

A generalized urticaria accompanied by an increase in the circulating eosinophiles developed in one patient (Case 1) on the tenth postoperative day. This patient had no history of allergic phenomena, and the differential blood count, preoperatively, was normal. A careful investigation of this patient revealed no evidence of sensitivity to the usual allergens. Symptoms rapidly subsided, and there has been no recurrence. This reaction led us to make daily differential white blood counts, postoperatively, on all patients in which methyl methacrylate was used. Four other patients were noted to develop an eosinophilia of 6 to 10 per cent between the seventh and tenth postoperative days. Examination of the fibrinous clot around the plastic balls removed at autopsy on Case 3 also revealed a preponderance of eosinophiles. This patient had a history of asthma prior to operation but showed no postoperative eosinophilia.

The mechanism of this response is being studied. Attention is called to the experimental studies of Spealman, Main, Haag, and Larson, in which mild sensitivity was noted in 20 per cent of subjects following local application of monomeric methyl methacrylate. No sensitivity was noted when the polymeric form was used locally or when implanted into the animals.

SUMMARY AND RESULTS

This paper is a preliminary report on the first fifteen patients in which an acrylic resin, methyl methacrylate, has been utilized to maintain a collapse of the lung for the treatment of pulmonary tuberculosis.

All of the patients were operated upon between July and December, 1945. All may be classified in the group of so-called good chronic patients, who have had an unsuccessful thoracoplasty, or who, because of their low vital capacity, advanced age, bilateral disease, and other complications, were unsuitable for thoracoplasty.

Thirteen of the patients have been improved by the operation; one has shown no improvement; and one is dead. Of the thirteen that have been improved, six have had negative sputum since operation.

The postoperative management of these patients was relatively easy. There were no infections. One patient developed a generalized urticaria on the tenth postoperative day, and four other patients were noted to have an increase in the circulating eosinophiles between the seventh and tenth postoperative days. One patient died on the eighth postoperative day with cardiac failure due to diminished pulmonary circulatory bed.

The author recognizes the fact that too few cases have been completed and that too short a period of time has elapsed since operation to evaluate the results of this form of collapse therapy; however, he feels that the experimental and clinical results so far warrant the continued use of this material. It adds to the surgeon's armamentarium a single-stage operation which can be used successfully in the treatment of patients not suitable for either thoracoplasty or resection. An evaluation of this operation will depend upon experience gained through its continued use.

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EPIDURAL ANESTHESIA IN THORACIC SURGERY

A Preliminary Report

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THORACIC physicians and surgeons in this country have taken advantage of recent advances in anatomic and physiologic knowledge pertaining to the lung and chest. However, they have failed to match this technical improvement with a corresponding advance in thoracic anesthesia. We are presenting, for the first time in this country, a report on a series of 100 cases of thoracic operations performed between October, 1945, and September, 1946, with epidural anesthesia. This anesthetic is being presented for consideration as an anesthesia which gives the operator a wide-awake and cooperative patient who is able to follow the surgeon's instructions during the operation. For example, he is a patient who can cough and raise sputum as indicated, thus reducing the incidence of postoperative spread of the disease process or of atelectasis. Further advantages of this type of spinal anesthesia are brought out in this paper.

The anesthesia is accomplished by injecting the anesthetic agent into the epidural space which lies between the dura mater of the spinal cord and the bony and fibrocartilaginous boundary of the vertebral canal.

The higher epidural, as distinguished from the caudal, which is a low form of epidural anesthesia, was first successfully used by Fidel Pages[1] of Spain in 1920, when he reported its use in forty-three cases of abdominal surgery. After his premature death, unfortunately, the subject was lost in obscurity until the reports by Dogliotti[2] of Italy and Gutierrez[3] of Argentina in 1932. Since that time, epidural anesthesia has been widely used in Europe and South America.

Very little mention of epidural anesthesia in thoracic surgery may be found in the English literature until 1941, when Rees and Abajian[4] stated it could not be used successfully in first stage thoracoplasties, but could be used in subsequent stages. In 1944, Vasconcelos[5] of Brazil, in reporting on esophagectomy for carcinoma of the esophagus, stated he has used epidural anesthesias for thoracoplasties, pneumonectomies, and lobectomies as well as for five total esophagectomies, and is convinced that it is the anesthetic of choice. In the section of Anesthesiology of the Proceedings of the Royal Society of Medicine for 1945, mention is made of Dawkins[6] of England now using epidural anesthesia for all his thoracic surgical cases.

ANATOMY AND PHYSIOLOGY

In order that the technique of administering and effecting this anesthesia be clearly understood, let us briefly consider the anatomy of the areas concerned.

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In the vertebral canal, we have from within outward (Fig. 1):

A. The spinal cord with its anterior and posterior roots
B. The pia mater, closely investing the spinal cord
C. The subarachnoid space, where the usual spinal anesthesia is given
D. The medullary layer of the dura mater, which lies adjacent to the arachnoid. A potential space exists between these two membranes, which is the subdural "space."
E. The epidural space lying between the dura mater and the membrane lining the vertebral canal.

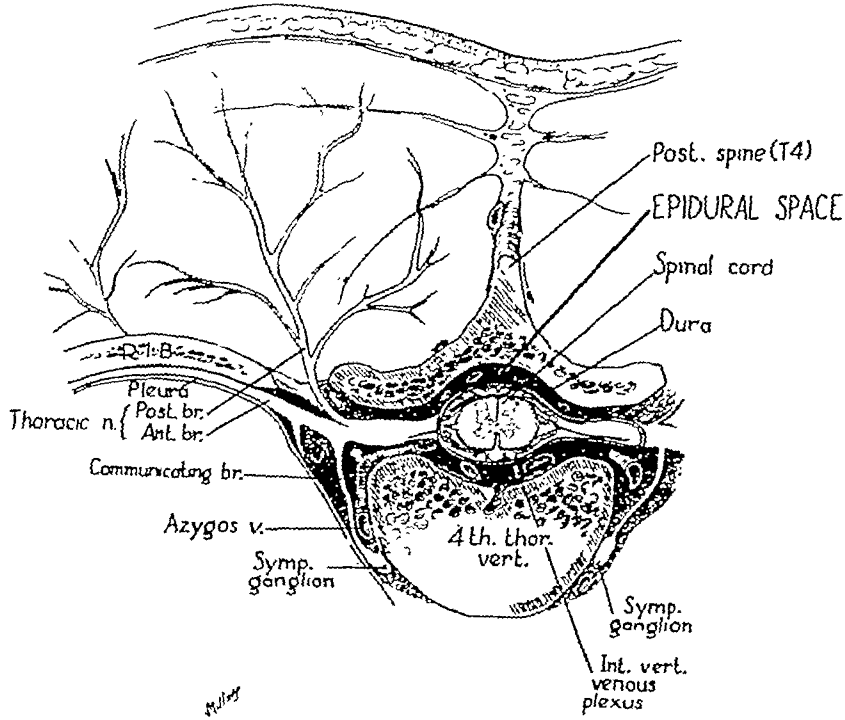

Fig. 1.—Illustrating the continuity of the epidural space with the paravertebral structures.

It is important to note that this epidural space is closed above at the foramen magnum by the fusion of the lining of the vertebral canal and the dura mater, that it extends the full length of the vertebral canal, and that it is closed at the sacrococcygeal juncture (Figs. 2 and 3). Laterally, this space communicates with the paravertebral tissue wherein lie the roots of the spinal nerves and the sympathetic ganglia with their gray and white rami communicantes. These ganglia extend from the first thoracic to the second lumbar segments.

The epidural space contains loose adipose and areolar tissue, venous and arterial plexus, and lymphatic vessels.

In 1927, Heldt and Moloney[7] found that a negative pressure of from minus one to minus 18 mm. of mercury exists in the epidural space. Bonniot,[8] in 1934, found that this negative pressure could be greatly increased by kyphosing the patient and flexing his neck. Gutierrez,[9] in 1932, first utilized this negative pressure in locating the epidural space by placing a drop of fluid in the hub of the needle, and slowly advancing the needle until the drop was sucked in. This is called Gutierrez' "drop sign."

The anesthesia is predominantly sensory. Thus, we have no impairment of the intercostal muscles, diaphragm, nor the accessory muscles of respiration. Dogliotti[2] has shown that little if any penetration of fluids and dyes takes place through the dura. The anesthetic in the epidural space thus cannot reach the subarachnoid space, nor can it reach the vital centers in the medulla, as it will be remembered the space is closed at the foramen magnum. The anesthetic solution can escape the vertebral canal only through the intervertebral foramina, where it bathes the spinal nerves and the sympathetic chain in the paravertebral tissue. The anesthesia is induced in the region of and lateral to the intervertebral foramina, where the medullary layer of the dura fuses with the perineurium of the spinal nerves. Dawkins[4] explains the sensory selectivity of the anesthesia as due to the relative large sizes of the motor nerves (2 to 20 micra) as contrasted to the smaller sizes of the sensory and sympathetic fibers (one-half to 2 micra); the anesthetic agent penetrating the smaller nerve fibrils with greater ease. This barrier to the anesthetic may be due to the medullary sheaths surrounding the larger nerves (Ranson[10]). Galley[6] thought it highly suggestive that the facility with which the neurones were

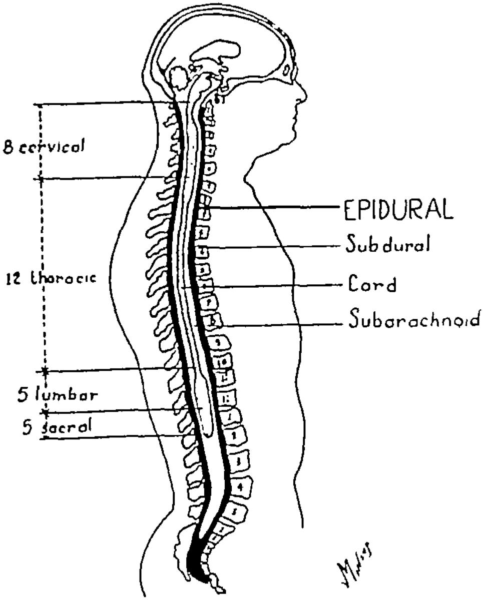

Fig. 2.—Schematic drawing illustrating the limits of the epidural space.

paralyzed corresponded closely with the size of the fibers, which in turn was largely determined by the degree of medullation. He further states that all the pain fibers are small and nonmedullated and are the most easily blocked, whereas the motor fibers have thick medullary sheaths and are least affected.

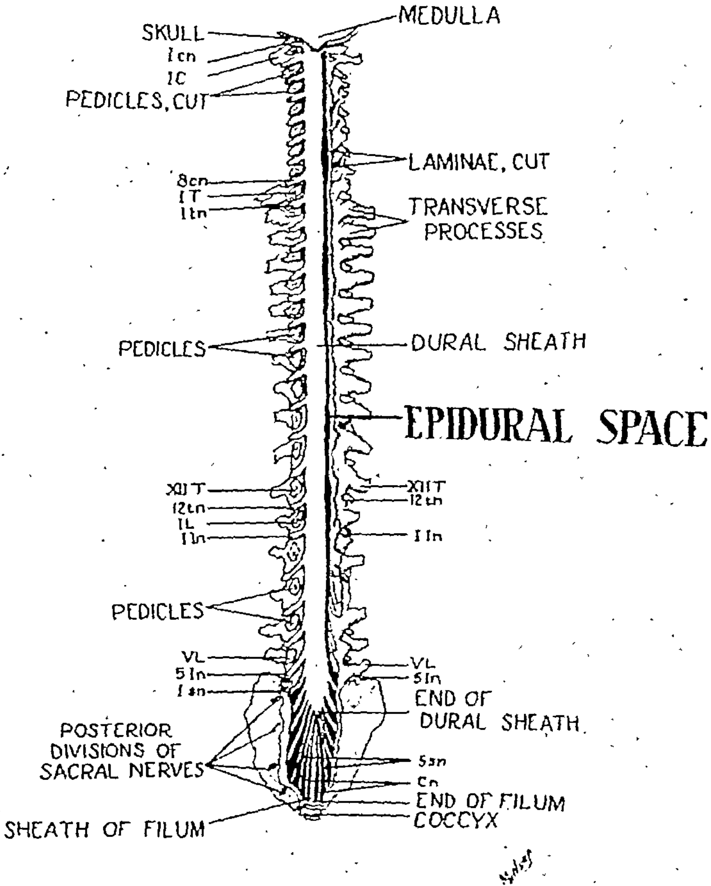

Fig. 3.—Posterior view of epidural space with lamina removed.

TECHNIQUE OF ADMINISTRATION

No special equipment is necessary for performing an epidural anesthesia. Special needles have been designed by Gutierrez, and various indicators for demonstrating the negative pressure in the epidural space have been recommended[11, 12] but we believe they are not necessary. The epidural tray consists of the following materials (Fig. 4):

One 10 c.c. syringe

Two 2 oz. medicine glasses or beakers, one containing physiological saline and the other for mixing the anesthetic

Twenty-five g. short hypodermic needle

Sharp 18 g. needle or a pointed B-P knife blade

Eighteen to 20 g. regular short bevel spinal needle

Ampules of novocaine and pontocaine
Adrenalin ampule
File.

We have used various concentrations of procaine (from one to 2 per cent), procaine-pontocaine mixtures, all with and without adrenalin. We also used 1½ per cent Metycaine on one occasion. For operations lasting up to 1½ hours, we now use the following mixture: 500 mg. procaine crystals, 20 mg. pontocaine ampule, 0.5 c.c. 1:1,000 adrenalin, in 40 c.c. physiological saline. If an operative procedure is expected to last over two hours, we use 600 mg. procaine and 40 mg. pontocaine with 0.5 c.c. adrenalin in 40 c.c. saline. With these amounts, we have found the anesthesia to extend over eight to ten spinal segments.

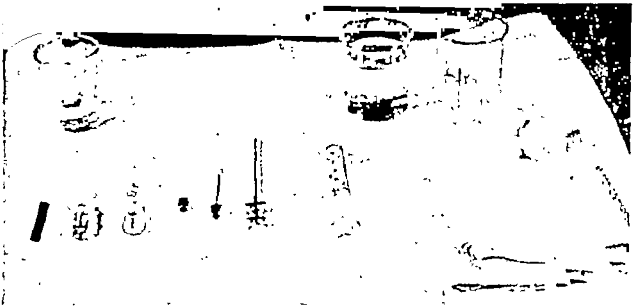

Fig. 4.—Epidural tray. The medicine glass on the left contains 1 per cent procaine for infiltrating the skin. Adrenalin is not shown on the tray, as in our clinic the nurse instills the adrenalin into the anesthetic solution.

To allay fear and apprehension, all patients receive a barbiturate (sodium Amytal gr.iii) the night before operation. They are given 1½ to 4½ grains of Nembutal one and one-half hours before and morphine sulfate gr. ⅛ to ⅙ with $\frac{1}{300}$ atropine sulfate forty-five minutes before surgery. The anesthetic solution is prepared after the patient arrives in the operating room.

The site of the puncture is chosen in an interspace in an area between the seventh cervical and the third thoracic spines. As gravitation aids in the downward diffusion of the solution, we prefer to administer the anesthetic with the patient sitting with his back bowed and head flexed. The assistant supports the patient securely in this position (Figs. 5 and 6).

After the anesthetic has been prepared and the site of puncture painted with antiseptic solution, a wheal is made exactly in the midline in the depression between the spinous processes. A small nick is made with the larger needle or knife blade in order that the short-bevelled spinal needle may be more easily introduced. The spinal needle, with the stylet in situ, is then introduced in the midline, paralleling the spinous processes of the interspace selected. One will quickly learn to recognize the various structures the needle penetrates by the differences in resistance. There is moderate resistance in penetrating the supraspinous ligament, slight in the interspinous ligament, and a rather marked resistance when the point of the needle meets the tough ligamentum flavum. At this point the stylet is removed and a drop of saline is placed in the hub of the needle. The needle is then very slowly advanced. When the ligamentum flavum is penetrated, a sudden "give" is experienced and at the same time the drop of saline will be sucked inward. Not infrequently a definite hissing sound is heard as the air is sucked into the epidural space.

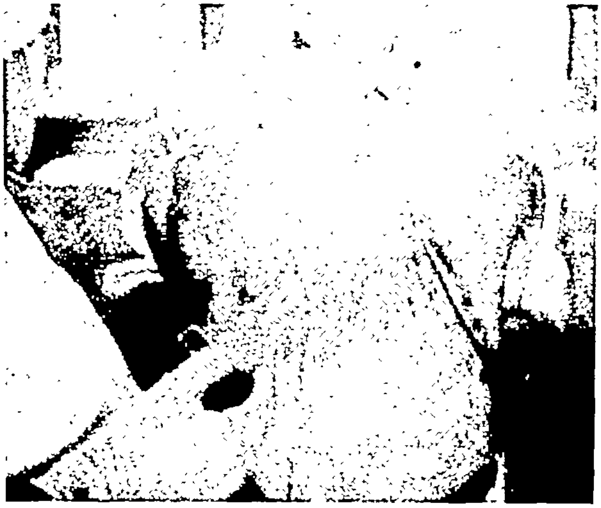

Fig. 5.—Showing how the assistant supports the patient.

With the syringe we then attempt to aspirate any spinal fluid or blood. A few cubic centimeters of air may be injected very easily as a further test, if one is within the space. If these various maneuvers satisfy us that we are within the epidural space, 10 c.c. of the solution is then injected, taking from ten to fifteen seconds. At this time, we give the patient $\frac{3}{8}$ to $\frac{3}{4}$ grain ephedrine sulfate or an equivalent of Methedrine by hypodermic. This is done at this time rather than earlier in order to avoid giving the ephedrine or Methedrine to one in which epidural anesthetic might be abandoned.

Earlier in our series, we waited three to five minutes, then tested the patient to see that a subarachnoid injection had not been made; a waiting period recommended by most of the various authors. Later, if we were confident of the position of the needle, this waiting period was eliminated. The remainder of the anesthetic was given at the same rate of ten to fifteen seconds for each 10 c.c.

After the administration, the patient was placed on the table with his operative side down for ten minutes in order to take further advantage of the dependent gravitation of the fluid.

Earlier in our series, if spinal fluid or blood were aspirated, the anesthetic was abandoned. Later another and even a third attempt in the adjacent interspaces either above or below was made in such instances.

OBSERVATIONS

The time consumed in the administration of the anesthetic varied from two to twelve minutes, averaging three and one-half minutes. The average time between the completion of the anesthetic and the beginning of the operative procedure was twenty-seven minutes; ten minutes of this time being consumed by the patient lying on his operative side, and the remainder in preparing the field and draping.

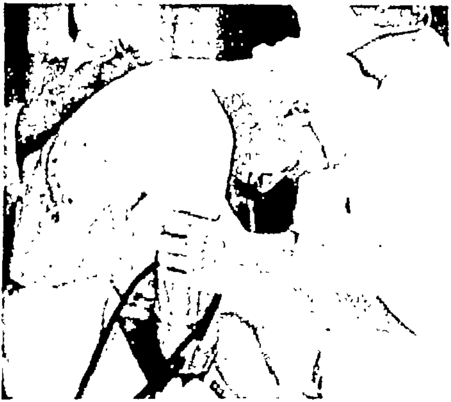

Fig. 6.—Demonstrating the angle at which the needle is introduced.

We have used epidural anesthesia in 100 thoracic operations on sixty-six patients (Table I). The youngest was a 16-year-old girl who underwent a thoracoplasty and the oldest a 65-year-old man who underwent a pneumonectomy for bronchogenic carcinoma. Their diagnoses and operative procedures are tabulated in Tables II and III. In addition, there were five other patients in whom the anesthetic was abandoned. In three of these cases spinal fluid was obtained and blood was aspirated in the other two.

The drop sign was used as a guide in locating the epidural space. In the first fifty cases, it was present in forty-six (92 per cent). In the second fifty cases, it was present in 100 per cent. Ruiz,[11] working in Gutierrez' clinic, reported a positive drop sign on 84 per cent of 415 gynecologic cases, where the injection was performed in the second lumbar interspace. We believe that when the technique is carried out correctly in the high dorsal region, the drop sign should be present in all cases.

The anesthesia has been classified under four categories: (1) excellent, absolutely no discomfort; (2) good, slight discomfort, not enough to warrant supplementary anesthesia; (3) fair, when supplementary anesthesia was used during *part* of the operation; (4) poor, when some other anesthetic was necessary throughout the operation. These results together with their relationship to the presence or absence of the drop sign are tabulated in Table IV. It will

TABLE I. 100 EPIDURAL ANESTHETICS, 66 PATIENTS

SEX	AGE GROUPS				
	16-20	20-40	40-60	60-65	TOTAL
Male	0	13	13	4	30
Female	5	27	4	0	36

TABLE II. DIAGNOSES

DIAGNOSIS	NO. PATIENTS
Pulmonary tuberculosis	39
Tuberculous bronchiectasis	3
Tuberculous bronchitis with stricture	4
Tuberculous empyema	4
Bronchiectasis (nontuberculous)	6
Lung abscess	4
Bronchogenic carcinoma	4
Exploratory, possible lung tumor	2
Total	66

TABLE III. OPERATIONS

OPERATIONS	NO.
Thoracoplasties (including 7 scapulectomies and 2 apicolyses)	
First Stage	32
Second Stage	25
Third Stage	18
Pulmonary Resections	
Lobectomy	6
Pneumonectomy	9
Exploratory thoracotomy	4
Rib resection and drainage	4
Secondary closure of bronchus	2
Total	100

TABLE IV

A—DROP SIGN

GROUP	PRESENT	ABSENT
First 50 patients	46 (92%)	4 (8%)
Second 50 patients	50 (100%)	0
Total	96	4

B—ANALYSIS OF ANESTHETIC AND RELATION TO DROP SIGN

GROUP	EXCELLENT	GOOD	FAIR	POOR
First 50	31—all Drop Sign	13—12 Drop Sign	4—2 Drop Sign	2—1 Drop Sign
Second 50	45—all Drop Sign	3—all Drop Sign	1—	1—
Total	76—all Drop Sign	16—15 Drop Sign	5—3 Drop Sign	3—2 Drop Sign
100 cases—Drop Sign present in 96 (96%)				

TABLE V. ANALYSIS OF FAIR AND POOR CASES

A. FAIR CASES (5)

1. Metycaine used. No drop sign. 50 to 60 per cent nitrous oxide analgesia throughout
2. Turned 10 minutes on opposite side. Drop sign present. Ten cubic centimeters ½ per cent procaine used in making incision.
3. Drop sign absent. 90 per cent nitrous oxide given twenty minutes at beginning
4. Drop sign present. 90 per cent nitrous oxide given fifteen minutes to allay nervousness
5. No pontocaine used. 85 per cent nitrous oxide analgesia twenty-two minutes during removal of ribs.

B. POOR CASES (3)

1. No drop sign
2. Drop sign present. By error, 30 c.c. saline given, followed by 45 c.c. anesthetic
3. After injection of one-half of solution, patient complained of dyspnea with wheezing, which disappeared in a few minutes. Anesthetic abandoned.

be noted that there were five cases in which the anesthetic was considered fair; four of these occurred in our first group of fifty. There were three cases in which the anesthetic was considered poor; two of these occurred in our first group of fifty. Analysis of the poor and fair cases is listed in Table V. This last patient who complained of dyspnea and wheezing was later found to be quite allergic to pontocaine by skin testing.

One patient complained of nausea during surgery, but there were no cases of vomiting on the operating table. In one patient, a 62-year-old male who was considered a desperate risk and who underwent an exploratory thoracotomy, the blood pressure dropped to zero and pulse and respirations ceased. He responded to stimulants, oxygen inhalation, and artificial respiration within a few minutes and the operative procedure was continued. Frequently, patients complain of dizziness during the administration of the anesthetic, especially if the anesthetic is injected too rapidly. This is probably caused by transmission of the increased pressure in the epidural space through the dura and arachnoid to the cerebrospinal fluid. The dizziness quickly passes on after completion of the procedure.

During the operative procedure, other than for the psychic aspect, the patients were quite comfortable and able to converse with the operator. They were encouraged to cough and expectorate when necessary. We are quite convinced that the preservation of the cough reflex alone constitutes one of the greatest advantages of epidural anesthesia, as the incidences of postoperative spreads, atelectasis, and aspiration pneumonias are reduced to a minimum.

Paralysis of the thoracolumbar outflow of the sympathetics also constitutes a great advantage of epidural anesthesia. As a result of this, the body remains warm and dry with a minimum of fluid loss, thus preserving the normal electrolyte balance of the body. Peripheral vasodilatation occurs, but this is partly neutralized by the administration of ephedrine. It is interesting to note that although a gradual drop in blood pressure occurs during operation, the increase in pulse rate is very slight. An average drop in blood pressure of 32 mm. systolic and 20 mm. diastolic with an average increase in pulse rate of 9.6 per minute was noted in the 100 cases. In twenty-eight cases, a gradual rise of the blood pressure, reaching a peak in about twenty minutes after completion of the injection, followed by a gradual drop was noted. None of our patients received a transfusion or an infusion in the operating room.

We have also noted a definite decrease in capillary bleeding as contrasted to general anesthesia with gas.

Postoperatively, it is gratifying to the surgeon to see a patient who has just undergone a major thoracic operation having little if any discomfort and able to help himself off the operating table. The analgesia following the anesthetic was noted to vary from two to twelve hours, averaging between five and six hours. Diets can be increased much more rapidly than with any other anesthetic. Two of these patients who underwent a thoracoplasty the day before Thanksgiving ate and enjoyed their turkey dinner the following day.

In eighty-one of the 100 patients the blood pressures were stabilized within one-half to two hours after operation. The remaining nineteen had various degrees of shock; that is, their blood pressures were unstable for periods up to seventy-two hours. Five of these patients died, and their causes of death are tabulated along with their operative risk in Table VI. It will be noted that the anesthetic was not responsible for any of these deaths.

TABLE VI. ANALYSIS OF DEATHS

NO.	SEX	AGE	OPERATION	RISK	COMMENTS
1	M	57	Exploratory Thoracotomy	IV	Died second postoperative day; autopsy, extensive carcinoma of left lung, pleura, kidneys.
2	F	25	Thoraco I	IV	Died fifth postoperative day; myocardial failure and pulmonary insufficiency; (V.C. 650 c.c.)
3	F	43	Thoraco III	III	Died thirty-second postoperative day; uremia.
4	F	56	Thoraco II	IV	Died second postoperative day; autopsy, hemorrhage from subscapular space filled pleural cavity through pleural tear
5	M	62	Pneumonectomy	III	Died 6 hr. postoperative; autopsy, massive intrathoracic hemorrhage.

Vomiting was noted in thirty-three patients postoperatively. Eleven of these ceased vomiting after changing from morphine to some other drug, and in one it was due to sulfamerazine. These figures also include those patients who gagged and vomited after violent coughing spells.

Two patients had a mild degree of abdominal distention and in one it was moderate.

Twenty patients required twenty-seven catheterizations, averaging 1.3 times per patient, all within the first twelve hours after operation.

One patient had a moderate headache and another had a severe headache lasting three days. This latter patient experienced a similar headache following a previous nitrous oxide anesthesia, and a slight headache following a subsequent epidural anesthesia.

Of the sixty-five patients, nineteen had previous or subsequent surgery under nitrous oxide anesthesia. On questioning these nineteen patients, fourteen, or 74 per cent, preferred the epidural anesthetic, four preferred gas, and one was noncommital.

COMPLICATIONS

Injection of the anesthetic agent into the subarachnoid space is the most serious error that can occur because of the high dosages used in epidurals as contrasted to the subarachnoid spinal anesthesias. This error can be avoided by careful observance of the technique. Fortunately, we have not had any cases in which this accident has occurred. Too rapid absorption of the anesthetic from the epidural space may cause varying degrees of toxic reactions. This, however, may be prevented to a large degree by the addition of adrenalin to the solution and the administration of ephedrine.

CONCLUSION

In surgery of the lung, pleural cavity, or the chest wall, the ideal anesthesia should aim at fulfilling certain criteria, namely:

1. It should be relatively easy to administer with a minimum of discomfort to the patient
2. Should be relatively nontoxic
3. Should provide for maximum oxygenation of the cardiorespiratory system that may be further embarrassed by operative manipulations
4. Should not contribute to shock
5. Should permit various degrees of positive pressure to a collapsed lung
6. Should be uninflammable if the use of the cautery is anticipated
7. *Should permit evacuation of the bronchopulmonary secretions, preferably* by preserving the cough reflex
8. Should assure minimum discomfort during the immediate postoperative course and should not alter nor delay the physiological process of healing.

There are *many distinct advantages of epidural anesthesia in thoracic* surgery when compared with the other forms of anesthesia now in use. It is superior to general gas anesthesia as it is much less toxic, having little effect on the heart, lungs, or kidneys; does not inhibit the cough reflex, and provides maximum oxygenation of the respiratory system with minimum deviation from the normal physiology during surgery. It can be given to those extremely poor risk patients who cannot tolerate another form of general anesthesia.

It is superior to local anesthesia, as a single puncture suffices, thus saving both time and discomfort. The patients are more comfortable and there is no distortion of the tissues nor delay in healing. It can be used in an infected field as empyema, lung abscess, or in cases with infected skin or subscapular space following a previous thoracoplasty.

In 1942, Schaffner and Found[14] reported the use of a high subarachnoid spinal anesthesia in 335 cases of thoracoplasty. There were no serious complications, although a high subarachnoid block sufficient for a first stage thoracoplasty requires anesthetizing the sixth cervical nerve. The margin of safety between accomplishing this and affecting the medulla is quite small. No such margin exists in epidural anesthesia in which the anesthetic agent, as we have emphasized, cannot reach the medulla. Furthermore, the potential danger of infecting the meninges is not present with an epidural anesthesia.

Compared with the three types of anesthesia mentioned above, the postoperative course with those cases in which epidural anesthesias have been used are in general much smoother and the patients are more comfortable.

There are, however, some disadvantages in its use. It requires a somewhat difficult technique. However, this is easily overcome by one experienced in performing spinal punctures. Three of us administered the epidurals, one of us in only three cases, all three of which had excellent anesthesias. Slightly more time is necessary; at least thirty minutes being required after the administration of the anesthetic until the operation can be started. Although some patients are psychologically unsuited for this type of anesthesia, this factor is of minor importance as the epidural can be supplemented by other forms of anesthesia.

The only contraindications to its use, we believe, are mechanical obstacles to its administration and hypersensitivity to the anesthetic agents used in epidurals. Calcification of the interspinous or yellow ligaments, obliteration of the epidural space, or infection in the region of the space may be obstacles to its use. With a positive allergic history, skin testing with the agents to be used is recommended.

After an analysis and comparison of the various forms of anesthesias, we are of the opinion that epidural anesthesia most closely approaches the ideal anesthesia for chest surgery.

SUMMARY

1. A brief history, physiology, and technique of administration of epidural anesthesia are discussed.

2. A series of 100 thoracic operations performed on sixty-six patients at the Missouri State Sanatorium is presented.

3. The results of these anesthesias are analyzed.

4. Comparison is made of the various types of anesthesias now being used in thoracic operations with epidural anesthesia.

5. Advantages and disadvantages of epidural anesthesia are presented.

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ADDENDUM

Since this paper was submitted for publication, epidural anesthesia has been administered in 203 additional cases with results paralleling those given in this paper.

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Original Communications

SURGICAL MANAGEMENT OF CARCINOMA OF THE LOWER TWO-THIRDS OF THE ESOPHAGUS AND CARDIAC END OF THE STOMACH

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NOTABLE achievements have been made in the surgical treatment of various lesions of the esophagus during the past eight years. This is particularly true of carcinoma of the esophagus when it occurs at or below the level of the top of the arch of the aorta.

When one considers that up to 1943 the only five-year cure of carcinoma of the esophagus was achieved by Torek[1] as a result of his successful operation in 1913, it is understandable that in 1940 Garlock[2] could write, "Heretofore, the diagnosis of carcinoma of the esophagus was tantamount to signing the patient's death warrant, and the physician advised palliative measures consisting of gastrostomy, radiation, or both." Because of the pioneer work of Adams and Phemister,[3] Garlock,[2] Churchill and Sweet[4] and others, such a situation no longer exists. Now the operative mortality for resections of carcinoma of this portion of the esophagus is not prohibitive, and it is being steadily lowered. The aggregate of figures published even recently cannot reflect the true picture, which is a fluid one and is constantly improving, so that recent operations resulting in probable cures will not be apparent as end results for some years. Moreover, as physicians become increasingly aware of the availability of surgical cure or palliation, more cases with earlier diagnosis will be sent to the thoracic surgeon for treatment, with a consequent improvement of end results.

In my opinion, the technical maneuvers that have given impetus to the increasingly satisfactory surgical treatment of cancer of the esophagus at or below the arch of the aorta, are the demonstration of the remarkable adaptability of the stomach to the thoracic cavity after adequate mobilization, and

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Garlock's[5] suggestion that the proximal segment of the esophagus be brought over and anterior to the arch of the aorta. By these means, esophagogastric continuity has been rendered feasible in a much larger group of higher lesions, and the known disadvantages of the Torek procedure have been obviated.

Churchill and Sweet[4] have suggested that the esophagus be considered in fourths, rather than the usual upper, middle, and lower thirds, and this serves a useful purpose in evaluating the problem of esophageal cancer from the anatomical aspect. As a matter of immediate practical significance, the location of all esophageal cancers at or below the arch of the aorta is important only as regards the necessity for completing the esophagogastric anastomosis either below the arch, leaving the proximal esophagus in situ, or above the arch, by bringing the proximal esophagus anterior to the arch. Frequently tumors located in the lower portion of the "midthoracic" esophagus may be resected with a safe margin, and esophagogastric anastomosis may be performed below the arch. The postoperative course is no different from tumors of the lower one-fourth similarly treated. It is on this vital point, in my own experience, that the survival rate hinges. Thus the operative mortality is from three to five times greater if the proximal esophagus is brought over the arch than if the same segment can be left safely in situ for anastomosis. It is suggested that future communications include this classification in reporting results.

The purpose of this paper is to report the author's experience with seventy-one patients with carcinoma of the esophagus and cardiac end of the stomach who were operated upon and of whom forty-six patients had forty-seven carcinomas which proved to be resectable, one patient being operated upon twice (case report). No claim for originality is made in any of the procedures described. The published works of the select group of pioneers in the subject have been drawn upon freely.

Although the operative results of the entire series is reported, it seemed desirable for purposes of contrast to break the series down into two groups, those prior to 1945 and those from 1945 to May 1, 1947. By way of partial extenuation of the early poor results, it may be said that many factors in the postoperative care during the war years were incredibly bad and during 1944 the problem was largely abandoned.

SELECTION OF CASES

Age.—The youngest patient who had successful resection was 52 years old; the oldest was 84 (Fig. 16). In no instance was a patient denied operation solely on the basis of age. It was our feeling that the general condition of the patient, and, in particular, that of the cardiovascular apparatus was of more importance than the chronological age. In one instance, a 72-year-old patient was operated upon while fibrillating. Fibrillation persisted during the entire operative and postoperative periods and the patient left the hospital in good condition.

Lymph Nodes.—As has been pointed out,[4] the involvement of cervical lymph nodes is relatively infrequent except in lesions high in the esophagus. In lesions below the arch, the lymphatic drainage tends to the periesophageal nodes, the subphrenic nodes, and the nodes in the region of the coeliac axis and left gastric arteries.

Metastases.—Metastatic lesions in the lungs should be carefully searched for by roentgenologic examination of the chest. In low esophageal cancers and cancers of the cardiac end of the stomach, rectal examination may reveal metastatic deposits in the pelvis. Involvement of the liver in esophageal lesions is a relatively late manifestation. When we have encountered it in high gastric lesions with involvement of the esophagus, we have proceeded to resection notwithstanding, for reasons of palliation. The tendency for the primary esophageal lesion to spread in the wall of the esophagus is well recognized, so that a relatively wide excision of the tumor should be made when possible.

Esophagoscopy.—We have operated upon only one patient with cancer of the esophagus without a positive tissue biopsy obtained at the time of esophagoscopy. When the esophagus is involved by high gastric cancer, it is frequently possible to make the diagnosis by biopsy through the esophagoscope. However, in this latter group, if a positive tissue diagnosis cannot be made, exploration is undertaken on the basis of roentgenologic findings or on suspicion alone.

Bronchoscopy.—At the time of esophagoscopy, a routine bronchoscopy is also performed. On at least four occasions, we have found the tumor invading the left stem bronchus or the trachea, which has obviated the necessity for exploration.

Roentgenological Examination.—Even when the esophageal cancer appeared extensive by this method of examination, in most instances we have chosen to explore the patient in order to give him the benefit of the doubt, although frequently we have only confirmed the x-ray findings.

PREOPERATIVE PREPARATION

Every effort is made to improve the patient's general condition, and to bring him to operation under optimal circumstances for his case. The oral hygiene is investigated by the dental consultant and careful prophylaxis and scaling is done. If any of the teeth are so badly involved as to preclude safe anesthesia, they are extracted. The blood picture is evaluated, and transfusions are given as necessary. Adequate parenteral fluids with amino acids are given in order to bring the blood protein up to a safe level. By the careful parenteral administration of fluids and electrolytes as well as the protein components, patients can actually be made to gain weight. Forty-eight hours before operation the administration of penicillin parenterally in doses of 50,000 units every three hours is begun. If there is complete or almost complete obstruction of the esophagus, lavage of the esophagus with half-strength Dakin's solution is undertaken twice a day beginning three or four days before the proposed time of operation. In a few instances, we have performed preliminary jejunostomy in order to improve the patient's nutrition preoperatively. Immediately before operation a continuous intravenous infusion is started, and in most of the cases the patients received blood continuously during the operation by one or more veins, as seemed indicated. Patients frequently receive from 1,000 to 2,500 c.c. of blood during the course of the operation.

ANESTHESIA

Anesthesia is induced with intravenous Pentothal and nitrous oxide and oxygen. Curare is given to facilitate the introduction of the intratracheal tube. The patient is then carried on intravenous pentothal with supplementary nitrous oxide and oxygen until the pleural cavity is opened, when the change is made to ether vapor and oxygen, on which he is maintained for the remainder of the operation. The use of the nonexplosive anesthetic in the early part of the operation permits the use of the endothermic coagulating current to secure hemostasis of the skin, subcutaneous tissues, and extracostal muscles. During the course of the operation, the lung is expanded at fifteen to twenty-minute intervals in order to facilitate re-expansion at the end of the operation.

OPERATIVE TECHNIQUE

A. *Carcinoma of the cardiac end of the stomach and carcinoma of the esophagus so situated that esophagogastric anastomosis may be made below the arch.*—The patient is placed in the right lateral decubitus position. A curving incision is made over the left ninth rib from the costochondral junction to within a centimeter or two of the spinous processes. If the carcinoma is situated in the esophagus and somewhat above the arbitrary division of the lower fourth, it may be better to select the eighth rib. In either case, the rib just above and below the rib selected for resection is divided by resecting subperiosteally a one-centimeter length just lateral to its respective transverse process. The intercostal nerve of the rib selected for resection is injected with one per cent Nupercaine in oil, as are two or three intercostal nerves above and below this rib. The rib selected is resected from the transverse process forward to within a centimeter or two of the costochondral junction. The pleural cavity is entered through the periosteal bed of this rib. Pads moistened with warm saline are placed over the wound edges and the Finochietto rib spreader is placed. Excellent exposure is thus obtained (Fig. 1). In none of our cases have we found it necessary to extend the incision across the chondral arch, so as to make a combined thoracoabdominal approach. The pulmonary ligament is now divided up to the inferior pulmonary vein and any bleeding vessels are secured. If the tumor is in the esophagus proper, the mediastinal pleura is incised, and, if possible, the esophagus is freed just above the hiatus and a tape passed around it. Before opening the diaphragm, operability of the tumor in the esophagus is determined, and by careful sharp and blunt dissection, the tumor is freed from the surrounding structures and dissection is carried upward around the esophagus for a suitable distance so that anastomosis may be made. There is relatively little blood supply to this segment of the esophagus, so that very few branches of the aorta are encountered, but when they are encountered they must be divided and ligated. No attempt is made to preserve the vagus nerves, which are sacrificed as necessary. If the tumor is operable, the phrenic nerve is now crushed as it lies on the pericardium just above the diaphragm. The diaphragm is opened by an incision extending from its lateral portion into the esophageal hiatus, during the course of which the subphrenic artery is secured and suture ligated (Fig. 2). If the primary tumor is in the stomach, the diaphragm may be opened at once with little preliminary dissection of the esophagus above the diaphragm. The vascular connections of the stomach now receive the attention of the operator. The gastrosplenic ligament is divided, and the vasa brevia are ligated. In most instances, it is not necessary to perform a splenectomy; however, if it interferes with mobilization of the stomach, or if there is involvement in the tumor mass, splenectomy is performed. The left gastroepiploic artery is divided, but care is taken to preserve the length of the vessel to serve as an anastomotic channel for bringing blood to the cardiac end of the stomach by dividing the branches in the gastro-colic omentum distal to it. Attention is now turned to the gastrohepatic ligament, which is divided between clamps, and the vessels are secured. In most instances, it is necessary to divide the left gastric vessels, following which the fundus of the stomach can be brought high into the chest. If the tumor is in the stomach, the tumor-bearing portion is resected between clamps and the distal portion is closed by a continuous chromic catgut suture and inverted with a second continuous chromic catgut suture. The suture line is further reinforced by a layer of interrupted silk sutures. If the tumor is in the esophagus and there is sufficient room between it and the cardioesophageal junction, the esophagus is divided between two ligature of No. 2 chromic catgut and the distal end is inverted into the stomach by means of a silk purse-string suture; this is reinforced with a layer of interrupted silk sutures (Fig. 3). The proximal end of the esophagus or stomach is now protected by a piece of rubber dam or a rubber

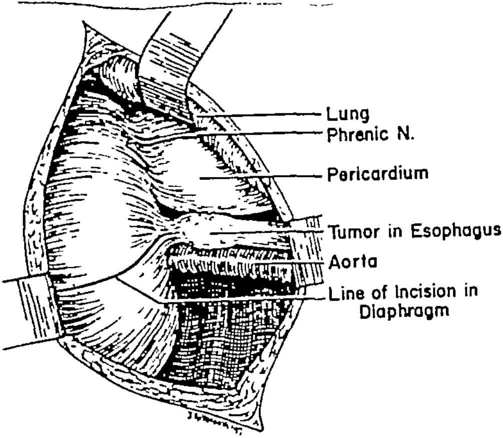

Fig. 1.

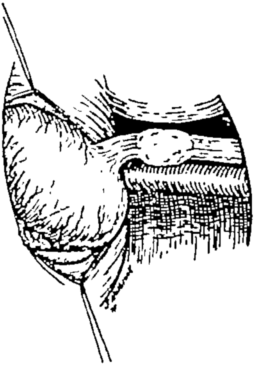

Fig. 2.

Fig. 1.—The left pleural cavity has been entered through the bed of the ninth rib. The mediastinal pleura has been incised and the tumor in the lower esophagus exposed.

Fig. 2.—The diaphragm has been opened from its lateral portion into the esophageal hiatus and the margins retracted by guy sutures. The vascular connections of the upper portion of the stomach have been ligated and divided.

glove. During the course of the dissection up to this point, all nodes that are encountered in the periesophageal and subphrenic regions and in the region of the left gastric artery are resected in so far as it is possible.

It is important not to resect the tumor-bearing portion of the specimen at this stage of the operation, since the esophagus retracts markedly and anastomosis is thereby rendered exceedingly difficult. Using the clamp on the proximal portion of the stomach or esophagus for gentle traction, the specimen is now lifted up out of the pleural cavity and on to the superior margin of the incision so as to present the mesial aspect of the esophagus for the first layer of the anastomosis with the stomach. The stomach is brought up into the chest, and a circular incision is made through the serosa and muscularis, as shown in Fig. 4.

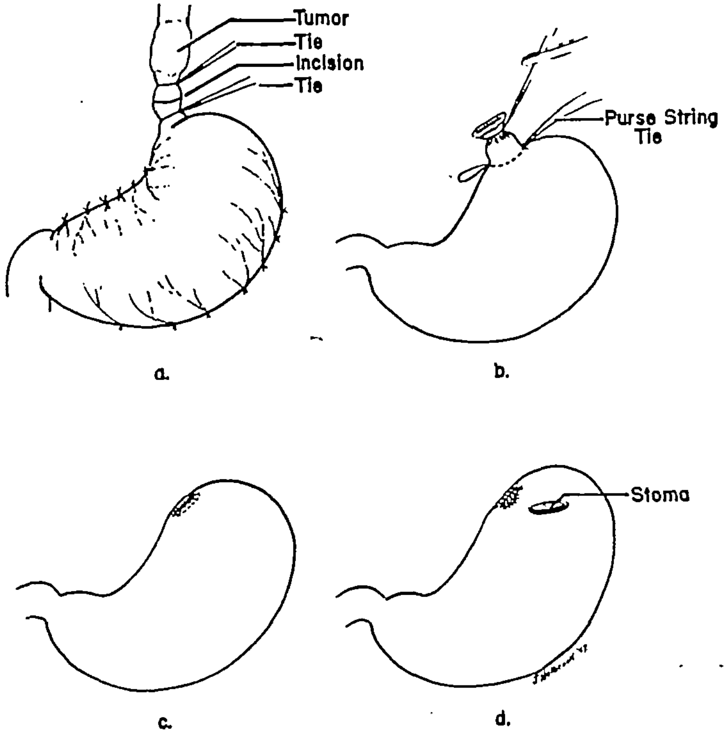

Fig. 3.—*a*, The esophagus is divided between two ligatures placed between the tumor and the stomach. *b*, The distal stump of the esophagus is invaginated into the stomach by purse-string suture. *c*, A reinforcing layer of interrupted silk is placed over the purse-string. *d*, An elliptical button of serosa and muscularis is removed at the site of the new esophagogastric anastomosis.

The button so outlined and composed of serosa and muscularis is dissected free without opening the gastric mucosa and the small vessels are secured by suture ligatures of fine silk close to the margins of the incision. A suitable location on the esophagus a sufficient distance above the tumor-bearing area to be judged above the farthest extent of the cancer is now selected, and the first or posterior row of sutures is placed. A three-layer anastomosis after the manner of Churchill and Sweet[4] using fine silk interrupted sutures with meticulous approximation of the mucosal layers is now made, as shown in Fig. 5. The esophagus is incised layer by layer as the anastomosis is made so that the second layer is muscularis of esophagus to muscularis and serosa of stomach. The esophagus is then completely divided somewhat on the bias to obtain a larger lumen, and the mucosal layer is completed. Following this, the anterior layer of muscularis of esophagus to muscularis and serosa of stomach is completed and the outermost layer of muscularis of esophagus to serosa of stomach is also completed.

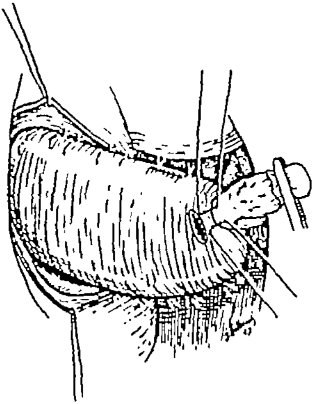

Fig. 4.—The stomach has been brought to the necessary height in the pleural cavity. The protected tumor-bearing portion of the proximal esophagus is brought out of the chest and over the superior wound margin and the first row (posterior) of interrupted silk, approximating muscularis of esophagus to serosa of stomach, is placed.

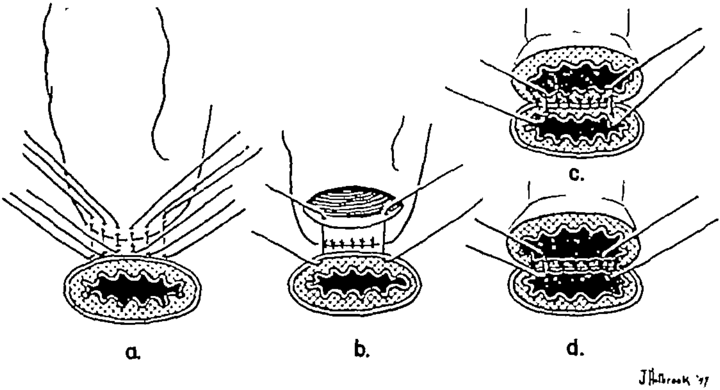

Fig. 5.—*a*, Posterior row of interrupted silk, approximating esophageal muscularis to gastric serosa, is placed. *b*, The second row of interrupted silk approximating cut edge of muscularis of esophagus to cut edge of gastric muscularis and serosa is begun. *c* and *d*, The meticulous approximation of mucosal layers, using fine interrupted silk with knots tied in the lumen, is begun posteriorly and will be completed.

A portion of omentum is next brought up and fixed about the anastomosis. The stomach is sutured to the contiguous pleura laterally by several interrupted silk sutures so as to relieve any strain on the anastomosis (Fig. 6). The diaphragm is next closed about the stomach with interrupted sutures and the lateral portion of the incision of the diaphragm is also approximated with interrupted silk (Fig. 7). The pleural cavity is flushed out thoroughly with warm normal saline and a fenestrated rectal tube for under-water drainage is placed in the pleural cavity through a lower interspace. The tip of this catheter is held in proper position by a loop of chromic catgut so that when the catheter is removed it will slip freely from the pleural cavity. The chest is now closed in layers after instilling 100,000 units of penicillin, and re-expanding the lung. Closure is effected by using interrupted No. 0 chromic catgut to the pleura and intercostal muscles, interrupted chromic No. 0 catgut to the extracostal muscles, subcutaneous interrupted No. 000 plain catgut and interrupted silk to the skin. After the dressing has been applied, the patient is placed on his back and bronchoscopy is performed so that the tracheobronchial tree is dry when the patient leaves the operating room.

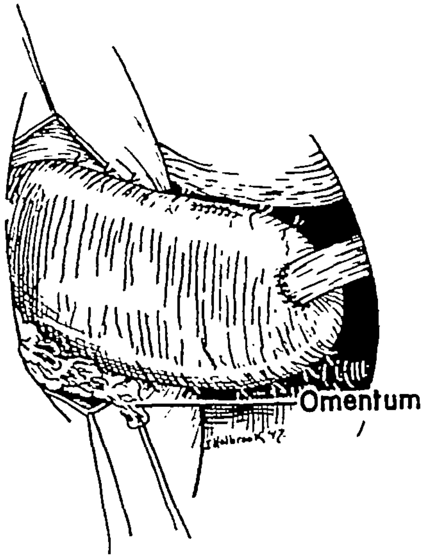

Fig. 6.

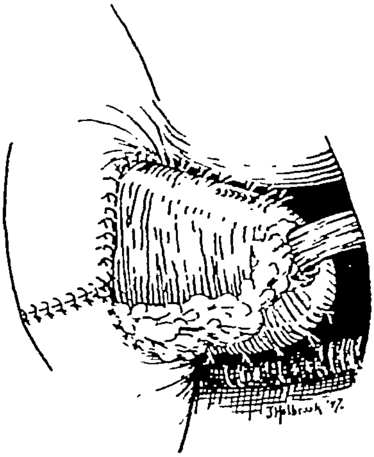

Fig. 7.

Fig. 6.—Anastomosis is completed. Stomach is anchored to contiguous pleura by interrupted silk sutures. Omentum is being brought up.

Fig. 7.—Diaphragm closed around the stomach by interrupted silk sutures fixing the stomach in position and closing possible sites of herniation. Omentum is sutured about anastomosis.

B. *Carcinoma of the esophagus located at or below the arch of the aorta requiring supra-aortic anastomosis.*—When the tumor in the esophagus is so high that it is judged it will be necessary to free the esophagus from under the arch of the aorta and bring it anterior to the aorta for anastomosis, the eighth rib is selected for resection and the seventh, sixth, and occasionally the fifth ribs are divided just lateral to their respective transverse processes in order to secure adequate exposure high in the thorax. The mediastinal pleura is incised and the free portion of the esophagus is delivered into the wound and a tape placed about it for traction. By careful blunt and sharp dissection, the esophagus with its tumor-bearing portion is freed from the surrounding structures. These include the inferior pulmonary vein, the left bronchus, and, on occasion, the posterolateral aspect of the pericardium in relation to the left auricle. It is frequently necessary to sacrifice a portion of the right pleura, in which case the anesthetist initiates positive pressure and a pack is placed against the defect until the operation can be completed. Dissection of the tumor and freeing of the esophagus from the under surface of the aortic arch is the most difficult part of this procedure and can be facilitated by working from below and above the arch in turn or simultaneously. It may be necessary to divide a few of the high intercostal arteries in order to turn the arch of the aorta outward and facilitate dissection beneath it. An incision of the mediastinal pleura posterior to the left subclavian artery with delivery of normal esophagus at this level so that a tape can be placed around it frequently aids the dissection (Fig. 8). It is at this level that the thoracic duct is encountered and may be injured. If it is injured and recognized, it should be ligated. If the tumor has

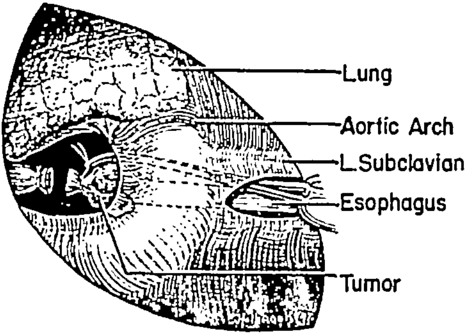

Fig. 8.—The tumor and proximal esophagus have been freed from beneath the arch and the esophagus divided between ligatures. The esophagus is divided lower than shown here so that the distal stump may be inverted into the stomach (Fig. 3). A clamp is indicated being passed deep to the aorta to grasp the proximal ligature and deliver the tumor-bearing portion over and anterior to the arch.

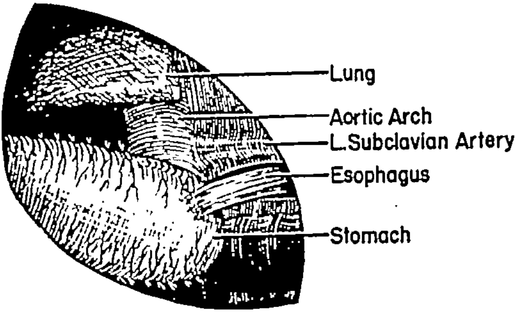

Fig. 9.—Esophagogastric anastomosis completed above and anterior to the arch of the aorta.

involved the prevertebral fascia, the plane of dissection may lie in the prevertebral space where troublesome bleeding from injury to the anterior external vertebral venous plexus may be encountered. When the esophagus has been freed and the tumor is found to be resectable, the diaphragm is opened, the stomach mobilized, and the esophagogastric anastomosis made as described above (operative technique, *A*). Anastomosis between stomach and esophagus above the arch is frequently difficult because of its relative inaccessibility; as has been pointed out by various authors, it should be made as high as possible in order to take advantage of the blood supply from the inferior thyroid artery, which is the sole blood supply of this portion of the esophagus (Fig. 9).

COMMENTS ON OPERATIVE TECHNIQUE

Incision.—In no instance has it been necessary to extend the incision across the chondral arch or otherwise to make a thoracoabdominal incision of the parietes. Adequate exposure has always been obtained as outlined above.

Avoidance of Trauma.—It is highly desirable, as Sweet[6] has pointed out, that the utmost care be observed in preserving the gastric blood supply. This is accomplished by avoiding the use of clamps or forceps on the stomach and by insuring that the important vessels concerned in the circulation of the stomach are not impaired in the course of division of their vascular connections in the gastroliental, gastrocolic and gastrohepatic ligaments.

It is also of importance that the esophagus be handled with great gentleness during dissection and when the anastomosis is made. To that end, no clamps or forceps are applied to that portion of the esophagus which will be left behind after anastomosis.

Inoperability as Determined at Operation.—In most instances a condition as deemed inoperable because of invasion of vital structures which could not be sacrificed with the tumor. Inability to separate the tumor from the aorta, bronchus, or inferior pulmonary vein obviously has led to the abandonment of the attempt at resection. No case has been encountered where resection of an invaded portion of the lung would render it operable, although this should be the simplest of procedures.

The spleen and tail of the pancreas have been repeatedly sacrificed and in one case most of the left lobe of the liver has been removed during the resection of a gastric cancer with survival of the patient in apparent good health fourteen months later.

Palliative Resections.—Although it has been apparent at operation that the cancer has spread beyond its original confines as manifested by lymph node involvement or liver metastases, if the primary growth was resectable it has been removed. It is felt that the palliation conferred by restoration of esophagogastric continuity and the ability to swallow food normally during even a short remaining life is ample justification for such an attitude.

Drainage.—In the earlier series the pleural cavity was not drained, reliance being placed on the sulphonamides and penicillin and repeated postoperative thoracenteses. As a result, there was a high incidence of pleural infections, some of which were fatal. Since routine drainage has been employed, serious pleural infections, except when there has been leakage at the anastomosis, have been negligible.

Bronchoscopy.—The role of bronchoscopy in the preoperative and postoperative care of patients who have been operated upon for carcinoma of the esophagus deserves a special comment. As has been mentioned, it is of the utmost importance that at the time of the esophagoscopy, bronchoscopy also be performed in order to rule out extension of the tumor to the tracheobronchial tree, and, in particular, to the left stem bronchus. At the conclusion of the operation, and after the patient has been turned upon his back, bronchoscopy is again performed so that the patient leaves the operating table with the tracheobronchial tree dry. As in any major thoracic procedure, the patient's inability to raise secretions postoperatively has been a frequent and troublesome complication. This can frequently be aided by intratracheal catheter suction, but in many instances it is necessary to perform bronchoscopy one or more times in the immediate postoperative days.

Complete occlusion of the left stem bronchus with complete atelectasis of the left lung has been encountered in four patients who have had the esophagus dissected from the left bronchus and the anastomosis made anterior to the arch of the aorta. This complication has been discussed by Strieder.[7] In one instance, the occlusion was due to an abscess which had formed in contact with the left stem bronchus as a result of a leak of the suture line. Two other patients died as a result of this complication. In the fourth patient, the edema subsided and the lung subsequently aerated. It has, therefore, been a source of some comfort to us to know that there was not actual involvement of the bronchus by tumor since it had been visualized at least twice before the complication arose.

COMPLICATIONS

Leakage of Anastomosis.—The complication of leak at the site of the esophagogastric anastomosis was the most frequent cause of death in our early series of cases. In the later series, from 1945 to 1947, it has been a rather infrequent complication occurring only three times in the last thirty-four cases. Such leaks occur on approximately the third or fourth day although they have been noted on the eighth day. The complication is usually obvious at once because the patient has marked elevation of temperature and, if the drainage tube is still in place, a foul discharge or particles of recently ingested food are apparent.

A roentgenogram of the chest reveals collapse of the lung because of the leakage of air into the pleural cavity through the anastomosis. Three of the patients who had anterior anastomoses and who developed leaks relatively late recovered. One sealed off the leak immediately and restored esophagogastric continuity and had no further difficulty in swallowing up to the time of his death eight months later from recurrence of the gastric carcinoma. The second was the re-operated case reported in this article. The esophagogastric continuity was restored by secondary healing but there has been troublesome narrowing at the site of anastomosis requiring dilatation at approximately two-month intervals. This patient, however, is alive and well and eating a full diet one year later (case report). The third patient, a 79-year-old man, developed a tiny leak which apparently did not result in an empyema but was demonstrated by a routine postoperative barium swallow which showed a small extravasation of the barium into the surrounding tissue. The patient is entirely symptom-free and has remained so eight months after operation. The fistulous tract is no longer demonstrable.

Atelectasis.—This has already been discussed, to some extent, under bronchoscopy. All patients exhibiting this complication postoperatively should be treated by bronchoscopy if adequate intratracheal catheter suction does not suffice to permit the lobe or lung to aerate. Where the esophagus has been brought anterior to the arch, the possibility of edema of the stem bronchus resulting from operative trauma must be borne in mind.

Late Strictures.—Narrowing at the site of the esophagogastric anastomosis, without evidence of recurrence of tumor, has been present in four patients of our later series.

Although the complication is an annoying and troublesome one, it has yielded satisfactorily to frequent dilatations and the patients have been able to carry on on a reasonably full diet. The possibility of the stricture being due to recurrence should be considered when the true situation may be revealed by esophagoscopy.

CASE REPORT

The following case is reported in some detail because of the unusual features and because, in so far as can be determined from the literature, it is the first time a patient has had two successful transthoracic partial esophagectomies.

J. N., a 63-year-old man, city park custodian, was admitted to the Massachusetts Memorial Hospitals on May 17, 1946, complaining of increasing dysphagia and loss of twenty pounds in weight of two months' duration. The dysphagia had progressed so that on admission he was able to swallow only liquids and these with considerable difficulty. His past history had no bearing on his present illness; he had always been well and strong. Up to the time of his weight loss, he had been considerably overweight. With the exception of Dupuytren's contracture of both hands, the physical examination and laboratory studies were within normal limits for a man of his age. Roentgenographic and fluoroscopic studies of the esophagus revealed narrowing and ulceration extending from 7 to 14 cm. above the diaphragm (Fig. 10).

On May 18, 1946, bronchoscopy revealed no abnormalities in trachea or major bronchi. At the same sitting, esophagoscopy demonstrated an annular constriction with ulceration 31 cm. from the upper incisors. Biopsy made at this time showed only chronic inflammation of the esophageal mucosa. In spite of the failure to obtain a positive tissue diagnosis, and in view of the typical appearance by esophagoscopy and roentgenography together with the classical history, operation was offered to and accepted by the patient.

On May 23, 1946, left transpleural esophagectomy with esophagogastrostomy below the arch of the aorta was performed without particular incident. It was necessary to free the tumor from the posteromedial aspect of the descending aorta to which it was adherent for a distance of several centimeters. There was no evidence of metastoses below or above the diaphragm.

The specimen showed epidermoid carcinoma of the esophagus with tumor cells in the periesophageal fibrous tissue. It appeared, microscopically, that the upper aspect of the tumor had been cut through at operation. The accompanying lymph nodes (subphrenic and periesophageal) were negative.

The patient had a benign postoperative course. He was allowed out of bed on the third and discharged home on the fifteenth postoperative day. On discharge from the hospital, he was eating a full diet with no dysphagia.

He was readmitted to the hospital on June 25, 1946, thirty-three days after operation, complaining of inability to swallow of three days' duration. He had had no difficulty until one week before when rapidly progressive dysphagia had supervened. Esophagoscopy was performed on June 27, 1946, and again on July 1, 1946. There was out-cropping of tissue at the site of anastomosis which bled easily and the lumen was occluded. Two biopsies showed only granulation tissue. Cautious attempts at endoscopic bougienage were unsuccessful.

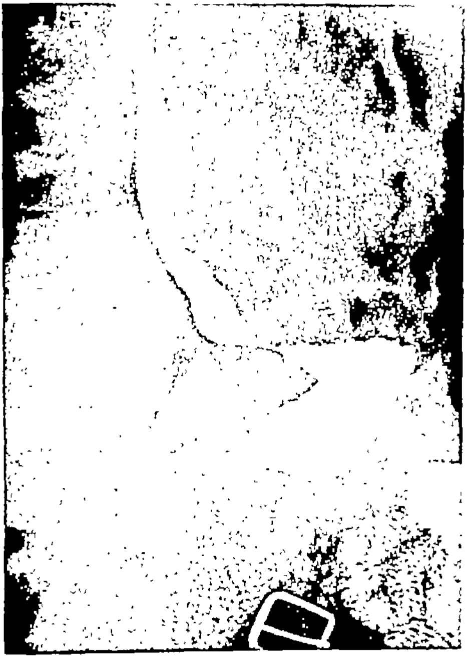

Fig. 10.—Roentgenogram after barium meal showing evidence of esophageal carcinoma extending from 7 to 14 cm. above the diaphragm. (Case report.)

Because of the pathologic findings in the specimen removed at the time of resection, the lack of evidence of extension of the growth other than locally, and the excellent condition of the patient at this time, it was decided to attempt further resection.

On July 3, 1946, the left pleural cavity was reentered through the bed of the seventh rib and with considerable difficulty, because of adhesions and indurated tissues, and the original site of anastomosis was resected with a wide margin of stomach and esophagus.

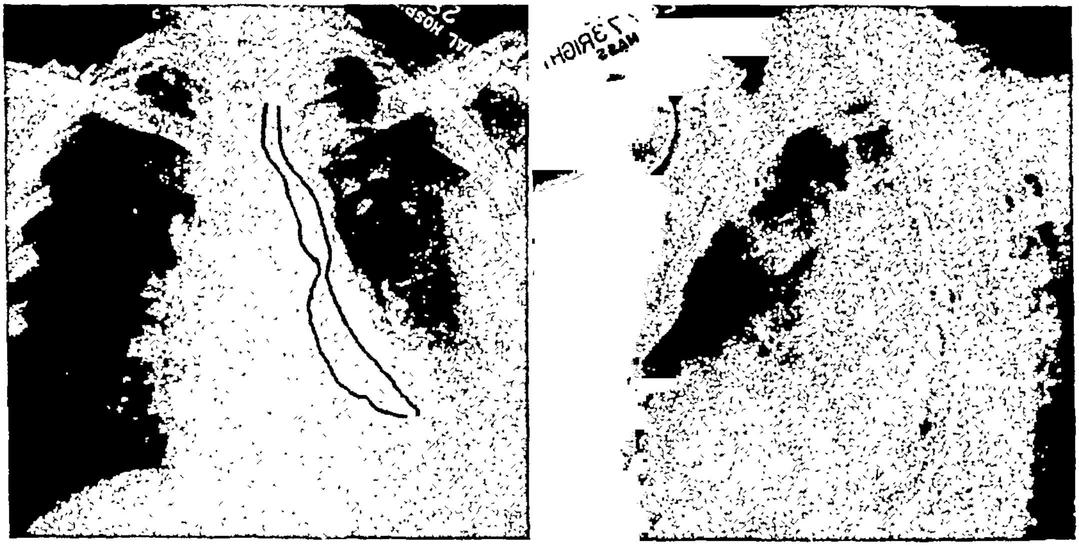

Fig. 11.—Roentgenograms after barium swallow showing restoration of esophagogastric continuity following second partial esophagectomy, secondary healing of partial disruption of suture line, and unroofing of complicating localized empyema.

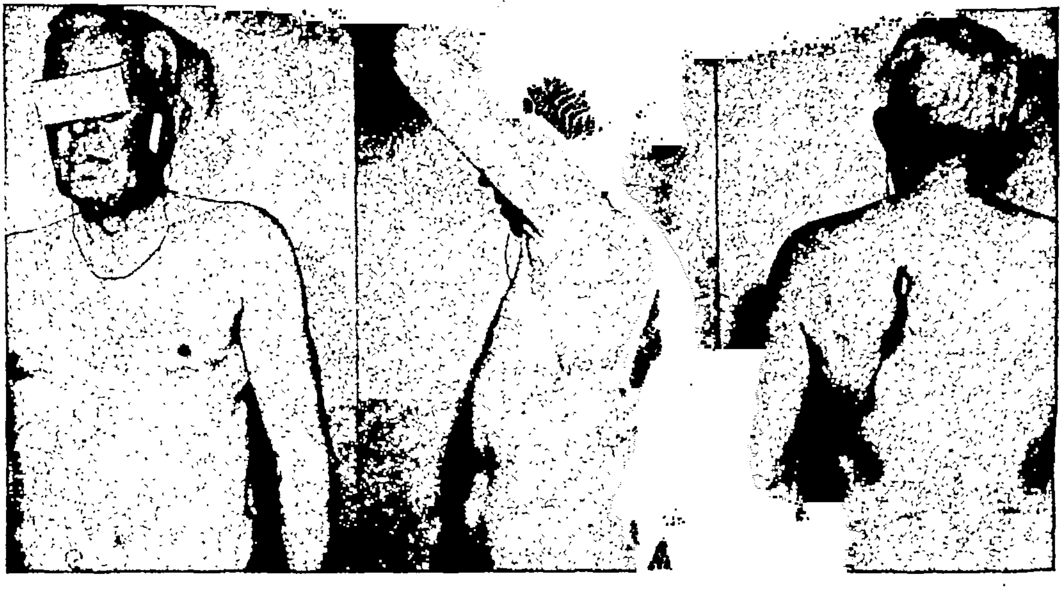

Fig. 12.—J. N. (case report) photograph taken April 28, 1947, at the time of the last esophageal dilatation. Shown are the scars of the jejunostomy and esophagectomy incisions as well as the healed empyema wound through which the esophagogastric fistula drained.

The proximal esophagus was brought over and anterior to the arch of the aorta and esophagogastric continuity again restored in the new position. There was, undoubtedly, some tension on the suture line because the stomach, after a tedious dissection, could not be mobilized completely satisfactorily.

Careful serial sections of the specimen removed showed no evidence of malignancy on histologic examination.

Three days postoperatively a leak developed at the site of anastomosis. This was confirmed by the appearance of methylene blue in the drainage tube immediately after it was swallowed by the patient. There was associated localized pyopneumothorax, which was small because of the diffuse pleural symphysis, the result of the original operation, which had been largely undisturbed, purposefully at the time of the second resection. The patient had little systemic reaction and the drainage tube was kept in situ. For the ensuing ten days, the patient's nutrition was maintained by parenteral fluids and transfusions with no essential deviations from normal blood chemistry. However, when it became apparent that there was a reasonable chance for survival, a jejunostomy was performed on July 16, 1946. The patient was then fed a mixture of "Gerolac" (Borden Co.) until he could again swallow with a gratifying maintenance of weight over a period of three months.

The small empyema cavity was unroofed by the resection of segments of several ribs on July 25, 1946. At this operation, the opening at the esophagogastric junction was visualized. There was separation of the anastomosis for about 50 per cent of the circumference. The empyema cavity was revised on Aug. 15, 1946, so as to remove overhanging edges and from this time, there was rapid closure of the cavity and of the esophageal fistula.

During September, 1946, the esophagus was dilated four times under general anesthesia and, with the closure of the fistula, he was able to swallow a full diet at the time of discharge from the hospital, Oct. 5, 1946 (Fig. 11).

Since discharge from the hospital, he has remained well and for the most part has been able to take a full diet except for several days prior to dilatation which has been necessary at intervals of approximately two months. At these times, esophagoscopy has been performed and there has been no evidence of local recurrence. There has been a gain in weight of 30 pounds (Fig. 12). The last dilatation was performed on April 28, 1947. (The patient remains well with no evidence of recurrence in January, 1948.)

RESULTS

An analysis of the total operative experience from 1941 to May 1, 1947 (Table I) reveals that there were seventy-one patients upon whom seventy-two operations were performed. Of these, twenty-five had exploration only, the condition being found inoperable. Forty-seven resections of either stomach or a portion of esophagus or both were performed on forty-six patients. One patient, discussed in brief above, had two resections of portions of the esophagus.

Anastomosis Below the Arch.—There were thirty-five resections of the cardiac end of the stomach or of the lower esophagus or both with esophagogastric anastomosis performed below the arch of the aorta. There were ten hospital deaths in this series, an operative mortality of 24.0 per cent.

TABLE I. TOTAL OPERATIVE EXPERIENCE (1941-1947)

	NUMBER	DIED IN HOSPITAL	OPERATIVE MORTALITY (%)
Total cases	71		
Total operations	72	19	26.3
Exploration only	25	1	4.10
Resections	47	18	38.2
Stomach and low esophagus with anastomosis below arch	35	10	24.0
Esophagus with anastomosis above arch	12	7	63.6
Torek	1	1	100.0

TABLE II. OPERATIVE EXPERIENCE (1941-1944)

	NUMBER	DIED IN HOSPITAL	OPERATIVE MORTALITY (%)
Stomach and low esophagus with anastomosis below arch	10	7	70.0
Esophagus with anastomosis, above arch	2	2	100.0
Torek	1	1	100.0

TABLE III. OPERATIVE EXPERIENCE (1945-1947)

	NUMBER	DIED IN HOSPITAL	OPERATIVE MORTALITY (%)
Stomach and low esophagus with anastomosis below arch	25	3	12.0
Esophagus with anastomosis above arch	9	5	55.5

Anastomosis Above the Arch.—There were eleven resections of carcinoma of the esophagus located sufficiently high in the midthoracic portion so that esophagogastric anastomosis was performed above the arch of the aorta after the suggestion of Garlock. Seven of these patients died in hospital, an operative mortality of 63.6 per cent.

Torek Operation.—There was one patient who had the Torek operation and who died in the hospital.

For purposes of contrast, it is of interest to divide the total operative experience into two series. The first, covering the period 1941-1944 and consisting of only thirteen cases, was accumulated during a period of meager experience and before standardization of procedure and postoperative care. The pleural cavity was not drained and penicillin was not always available. The results were bad. The second, covering the period 1945 to 1947 (May 1), consists of thirty-four cases treated by the two standard operations described above and having the benefit of previous experience in postoperative care. The pleural cavity was always drained and all patients had the benefit of penicillin. The results were considerably improved.

Operative Experience 1941-1944.—There were thirteen operations (Table II).

Anastomosis below the arch: There were ten resections of the cardiac end of the stomach or of the lower esophagus or both with esophagogastric anastomosis performed below the arch of the aorta. There were seven deaths in hospital, an operative mortality of 70 per cent.

Anastomosis above the arch: There were two resections of esophageal cancers situated so high in the midthoracic esophagus that esophagogastric anastomosis was performed above the arch of the aorta. Both of these patients died in hospital.

Torek operation: One patient had the Torek operation and died in hospital.

Operative Experience 1945 to May 1, 1947: There were thirty-four operations (Table III).

Anastomosis below the arch: There were twenty-five resections of the cardiac end of the stomach or of the lower esophagus or both with esophagogastric anastomosis performed below the arch of the aorta. There were three deaths in hospital, an operative mortality of 12.0 per cent.

Anastomosis above the arch: There were nine resections of esophageal cancers situated so high in the midthoracic esophagus that esophagogastric anastomosis was performed above the arch of the aorta. There were five deaths in hospital, an operative mortality of 55.5 per cent.

Survivors: Of the twenty-six operative survivals, twenty-one patients are still alive from one month to fourteen months later, on May 1, 1947, when

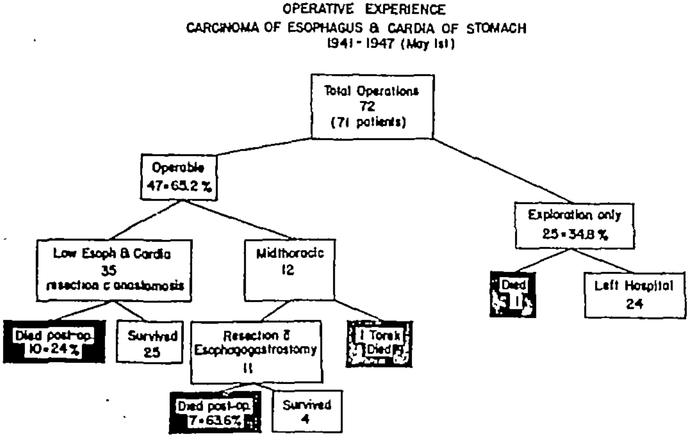
OPERATIVE EXPERIENCE
CARCINOMA OF ESOPHAGUS & CARDIA OF STOMACH
1941 - 1947 (May 1st)
Total Operations 72 (71 patients)
Operable 47 = 65.2 %
Exploration only 25 = 34.8 %
Low Esoph & Cardia 35 resection c anastomosis
Midthoracic 12
Died 1
Left Hospital 24
Died post-op. 10 = 24 %
Survived 25
Resection c Esophagogastrostomy 11
1 Torek Died
Died post-op. 7 = 63.6 %
Survived 4

Fig. 13.

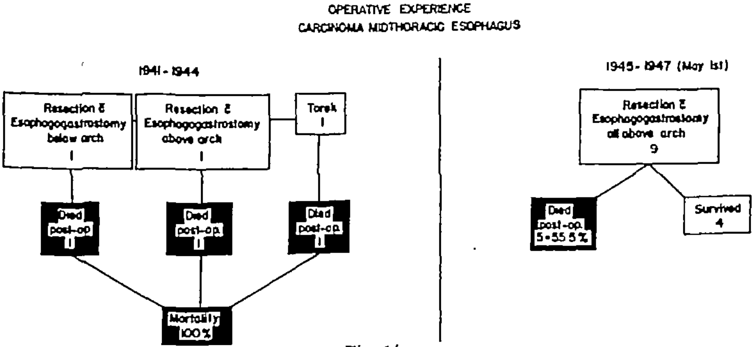
OPERATIVE EXPERIENCE
CARCINOMA MIDTHORACIC ESOPHAGUS
1941 - 1944
Resection c Esophagogastrostomy below arch 1
Resection c Esophagogastrostomy above arch 1
Torek 1
Died post-op 1
Died post-op. 1
Died post-op. 1
Mortality 100 %
1945 - 1947 (May 1st)
Resection c Esophagogastrostomy all above arch 9
Died post-op. 5 = 55.5 %
Survived 4

Fig. 14.

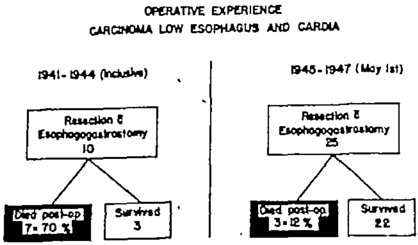

Fig. 15.

this is written (Table IV). One is alive with disease four months postoperatively, after a subtotal gastric resection. The remainder show no evidence of disease clinically, although a few are known to have disease left behind at operation, and others will undoubtedly manifest recurrences sooner or later.

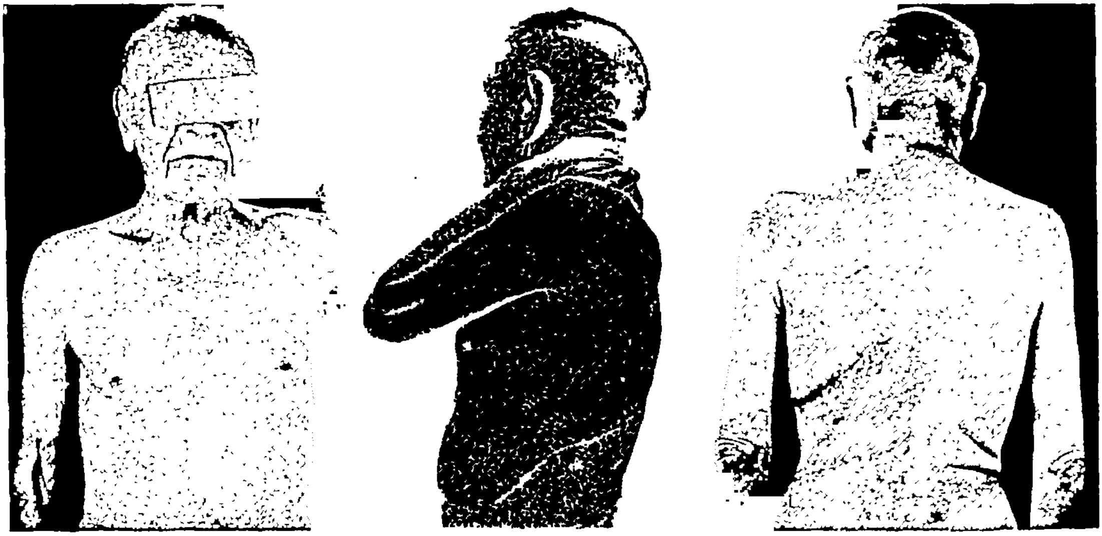

Fig. 16.—I. B., 84-year-old man who had successful transpleural esophagectomy and esophagogastric anastomosis below the arch for carcinoma occurring in the lower midthoracic esophagus. Photograph made six weeks after operation which was performed April 1, 1947. The scars of the operative incision and drainage site are shown in the lateral and posterior views. This patient had Hodgkin's disease of the nasopharynx at age 72, treated by radiation with apparent recovery.

The age distribution of the survivors is shown in Table V. The two oldest survivors are aged 80 and 84 years, respectively. The 84-year-old survivor had histologically proved Hodgkins' disease of the nasopharynx at age 72 treated by radiation and is without evidence of recurrence at this time (Fig. 16). Two other patients in the total series operated successfully had a second primary cancer. One, aged 60 years had a grade III carcinoma of the lip excised seven and one-half months before esophagectomy with anastomosis above the arch, and is now well thirteen months later. The other died one month after transthoracic gastrectomy with a primary carcinoma of the colon.

Table IV. Duration of Survival

MONTHS	NUMBER
1-6	9
6-12	8
12-14	4
Total	21

Table V. Ages of Survivors

AGE (YR.)	NUMBER
50-59	5
60-69	9
70-79	5
80-84	2
Total	21

SUMMARY

1. The experience with seventy-two operations on seventy-one patients with carcinoma of the esophagus occurring at or below the arch of the aorta, and of the cardiac end of the stomach, is presented.

2. The preoperative preparation, the operative technique, and the postoperative complications are discussed.

3. It is suggested that in reporting results, the division of cases into (1) those in which esophagogastric anastomosis was made below the arch of the aorta and (2) those in which it was made above and in front of the arch of the aorta, is of greater immediate practical significance because of the marked differences in operative mortality than is indicated by the arbitrary anatomical divisions into thirds or fourths.

4. The complication of occlusion of the left stem bronchus due to edema following dissection of the esophagus from the bronchus is reported as occurring in four patients.

5. A case is reported in some detail because of the unusual features and because, in so far as can be determined from the literature, it is the first time a patient has had two successful transthoracic partial esophagectomies.

6. The results of the total operative experience are reported in detail.

The author takes pleasure in expressing his indebtedness to the following surgeons who have collaborated with him on several of the cases included in this report: Dr. Edward A. Cooney, Boston City Hospital; Dr. Charles Szikhas, Dr. Thomas Anglem, and Dr. Hollis L. Albright, Massachusetts Memorial Hospitals.

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CONGENITAL ESOPHAGEAL ATRESIA AND TRACHEOESOPHAGEAL FISTULA

CLAYTON G. LYON, M.D., AND (BY INVITATION) STANLEY G. JOHNSON, M.D.
SAN FRANCISCO, CALIF.

IN A recent review of the literature, we have been able to find reports of approximately 468 cases of esophageal atresia with or without tracheoesophageal fistula. There has been a renewed interest in the condition and an increased number of successful cases have been reported since the first successful repairs reported by Leven,[1] and by Ladd[2] in 1939.

The anomaly appears to assume several forms classified by Vogt[3] in three main categories and classified under five main types by Ladd (Fig. 1).

Class 1: The upper esophageal segment terminates in a blind pouch in the upper third and the lower esophageal segment is represented by a similar blind pouch, there being no communication with the trachea.

Class 2: The upper esophageal segment communicates with the trachea and the lower segment is a blind pouch.

Class 3: The upper segment terminates blindly and the lower segment of the esophagus communicates with the trachea above the carina.

Class 4: This is similar to *3* except that the lower segment communicates with the trachea at the carina or with the right or left main-stem bronchi.

Class 5: Both segments communicate with the trachea.

In Fig. 1 we have tabulated the types of anomaly as reported in three large series of cases in which the authors have been able to determine that type which existed. In eighty-four cases, seventy-six or eighty-six per cent, were found to have an upper esophageal segment that terminated blindly, and a lower segment that communicated with the tracheobronchial tree by means of a fistulous tract.

The diagnosis is suggested by increased oral secretions, attacks of cyanosis, or the regurgitation of feedings. Confirmation is obtained by passage of a small catheter into the esophagus which meets an obstruction in the upper third, or fails to enter the stomach. The patient is then fluoroscoped while one-half to one cubic centimeter of lipiodol is introduced through the catheter, thus demonstrating the upper segment with or without its tracheal communication. The inferior level of the upper esophageal segment is elevated during the act of deglutition. Therefore, one should determine this level during and between the acts of deglutition under fluoroscopy rather than relying on a roentgenogram for this information. Following the examination, the Lipiodol should be aspirated as it is easily regurgitated and enters the tracheobronchial tree. Roentgenograms of the chest and abdomen are valuable in determining the condition of the lung fields, the presence or absence of other anomalies, and the presence or absence of gas in the gastrointestinal tract. In some instances,

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From the Department of Thoracic Surgery, University of California Medical School.

Read at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29 and 30, 1947.

lipiodol which may have been regurgitated by the infant will demonstrate the tracheobronchial tree and occasionally the lower esophageal segment. Gas in the gastrointestinal tract is usually indicative of a fistula. However, Haight records two instances in which the lower segment communicated with the trachea and in which gas was not present in the gastrointestinal tract.

Successful surgical management has been developed and reported by Haight and Towsley,[4] Humphreys,[5] Ladd and Swenson,[6] Gross,[9] Leven,[1] and others. The number of successful repairs is rapidly increasing as a result of earlier diagnosis and constant improvement in anesthesia and surgical management. The early methods of dealing with this anomaly were encouraging but certainly not ideal. The multiple stage procedure with eventual construction of an antethoracic esophagus resulted in the first successful repairs. Subsequently, the development of a plan of direct attack with primary anastomosis of the esophageal segment by an extrapleural approach have proved very successful in those cases in which the esophageal segments are in close approximation. It would appear from a review of the literature that approximately 85 per cent of the cases may be managed by the direct approach. However, there still remains approximately 15 per cent of the cases in which the esophageal segments are so widely separated that the anastomosis cannot be done and in those infants the multiple stage procedure is necessary.

Encouraged by the good results of children undergoing intrathoracic operation under intratracheal anesthesia, and discouraged by the prolonged and difficult course of the multiple-stage operations, we have attempted a transpleural approach under intra-tracheal anesthesia in a small series of cases. In those infants in whom an anastomosis of the esophageal segments is not possible we have contemplated an esophagogastrostomy, fully aware of the fact that such a procedure is one of great magnitude in the newborn infant. In the past six months we have encountered four infants with this congenital anomaly and for whom we have used a transpleural approach under intratracheal ether and oxygen anesthesia.

Ladd mentions the use of the transpleural approach in seven patients with one success, and the successful transpleural ligation of the fistulous tract in one other instance. He also mentions that R. H. Franklin, in 1941, used the transpleural approach in one infant. Haight records one case in which the transpleural approach was used. It has been commonly felt that the transpleural procedure is one of considerable hazard because of the low pulmonary reserve of infants, and that a surgical procedure of this magnitude was attended with considerable shock. It has been also stated that general anesthesia might be less well tolerated and that local anesthesia using the extrapleural approach is preferable. However, many operators using the extrapleural approach have found that the reconstruction of the esophagus is much more satisfactory when using general anesthesia. They feel that there is much less movement of the esophagus and, therefore, less technical difficulty in performing the anastomosis. Furthermore, the pleura is frequently inadvertently opened when the extrapleural approach is used, resulting in pneumothorax.

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On Oct. 25, 1946, at the age of 60 hours, the infant was operated upon under ether and oxygen anesthesia as outlined below. A blind upper esophageal segment was found. When the upper segment was mobilized it could be drawn down to a point just above the arch of the aorta. The lower segment of the esophagus was approximately 1.5 cm. long and there was no communication with the trachea. The diaphragm was opened, the vessels of the greater and lesser curvatures were divided down to the prepyloric region, and the stomach was delivered into the pleural space. The lower esophageal segment and a portion of the adjacent lesser curvature 2 cm. in length were excised, and the stomach inverted. The resultant gastric tube could be delivered to a point just above the level of the aortic arch where end-to-side esophagogastrostomy was carried out using two rows of interrupted fine cotton suture. The blood supply to the stomach appeared adequate and there was no undue tension. The diaphragm was closed, its margins were sutured to the stomach, and the site was covered with pleura. The chest wall was closed in layers with fine cotton sutures. The surgical procedure required four hours and twenty-five minutes. At completion of the procedure the infant's condition was considered only fair. Shortly thereafter, a considerable amount of mucoid material was aspirated from the pharynx and one attack of cyanosis occurred. There was no evidence of laryngeal edema.

Because of the Mongolian idiocy exhibited by this infant, the postoperative care was not to be especially energetic. However, on the first postoperative day, the infant received an unplanned feeding of 2 oz. of formula, which was regurgitated immediately and aspirated. Aspiration pneumonia developed and resulted in death forty-eight hours after surgery.

Autopsy revealed that the blood supply to the stomach had been adequate and the anastomosis was intact. The bronchial tree contained a considerable amount of brown mucoid material. There was extensive bilateral pneumonia.

CASE 2.—B. O., a premature female infant weighing 3 pounds and 7 ounces at birth, was admitted to the University of California Hospital 102 hours after birth. At another hospital where she was admitted shortly after a precipitant delivery at home, it was noted that all feedings were regurgitated, that excessive mucus frequently was present in the mouth and nasopharynx, and that attacks of cyanosis occurred with periods of apparent respiratory difficulty. Despite this information, a diagnosis was not established until the fourth day of life, when attempts to pass a catheter into the stomach met an obstruction in the upper esophagus. Thereafter, fluoroscopy revealed gas in the stomach and small bowel; equivocal evidence of pulmonary infiltration on the right; and, with thin barium as a contrast media, a blind upper esophageal segment extending to a level opposite the mid-portion of the third thoracic vertebra.

On entry the infant appeared active but cried feebly. She was markedly dehydrated and moderately icteric. Physical findings otherwise were essentially normal except for equivocal evidence of pneumonitis at the right base. There were no other obvious anomalies.

Several hours were consumed in attempting to improve her general condition. The regime included frequent nasopharyngeal aspirations, continuous administration of oxygen, parenteral injections of plasma, blood, glucose in Ringer's solution, and penicillin.

On Nov. 6, 1946, at the age of 120 hours, under intratracheal ether and oxygen, the transpleural approach mentioned below was carried out. A blind upper esophageal segment was encountered. The lower esophageal segment communicated with the trachea, entering that structure just above the carina. After mobilization of each esophageal segment, the esophageal portion of the fistula was ligated with fine cotton, divided, and the fistulous stump transfixed distal to the ligature with a similar suture. An anastomosis was carried out after rotating the distal segment clockwise through 180 degrees as suggested by Gross. Again attempt was made to take tension off the suture line by suturing the wall of each esophageal segment to the mediastinal tissue. After pleuralization, the wound was closed in layers with interrupted fine cotton sutures.

The operation required one hour and fifty-five minutes, and the infant received parenteral glucose in Ringer's solution and blood during the procedure. At the completion of the operation, her general condition appeared to be no worse than it was on her entry to the operating room.

Postoperatively, however, there was more and more respiratory difficulty, with gradually increasing physical signs of bilateral pneumonia. Associated with these findings were persistent excessive oral and nasopharyngeal mucous accumulations that required aspiration. Death ensued nineteen and one-half hours after completion of the surgical procedure.

Autopsy revealed extensive bilateral pneumonia. The esophageal anastomosis admitted nothing larger than a 2.5 mm. probe, the obstruction apparently resulted from inversion of too much esophageal wall rather than from rotation of the lower segment. Both esophageal segments appeared as though they had been viable, and there was no undue tensions on the anastomosis.

Case 3.—B. B., a seven months premature male infant, delivered following a pregnancy complicated by placenta previa, weighed 3 pounds, 15 ounces at birth. Physical examination at that time revealed no obvious abnormalities. On the third day, excessive oropharyngeal secretions were noted.and the infant regurgitated its feedings through its nose and mouth. This was associated with attacks of cyanosis and difficulty in breathing. At that time examination revealed bilateral, coarse, wet pulmonary râles. A catheter could not be passed beyond the upper portion of the esophagus. Fluoroscopy with lipiodol as contrast media revealed an apparently blind upper esophageal segment. Gas was seen in the stomach and small bowel.

The infant was transferred to the University of California Hospital and prepared for surgery by a regime which included aspiration of the oropharynx, continuous administration of oxygen, parenteral administration of saline, glucose, plasma, and penicillin.

On Nov. 16, 1946, at the age of 88 hours, the infant was operated upon under ether and oxygen intratracheal anesthesia as outlined below. A blind upper esophageal segment was encountered. The lower esophageal segment communicated with the trachea entering that structure just above the carina. Each esophageal segment was mobilized. The lower segment was divided just below its entrance into the trachea, the fistulous esophageal stump was ligated with fine cotton material and transfixed distal to the ligature with similar material. A very satisfactory end-to-end anastomosis between the two esophageal segments was carried out as described below without apparent tension and without rotating the lower segment. The site was covered with pleura and the wound was closed in layers with interrupted sutures of fine cotton.

The procedure required two hours and forty minutes. The condition of the infant at the completion of the procedure was considered quite satisfactory.

During the first seven days postoperatively, the infant was maintained on a regime of frequent oropharyngeal aspirations, continuous oxygen, no oral feedings, and parenteral administration of saline solution, glucose, plasma, blood, and penicillin. During this period the infant seemed to handle its oropharyngeal secretions fairly well.

Thereafter the infant was fed but almost immediately began to regurgitate and aspirate its feedings. Occasionally this resulted in episodes of respiratory difficulty associated with cyanosis. Therefore, feeding attempts were discontinued for a time and the infant was maintained on parenteral fluids, plasma, and blood. On the ninth postoperative day, a small amount of lipiodol was instilled into the pharynx under fluoroscopic vision. The lipiodol was delayed for a short time at the site of the anastomosis and then a narrow trickle passed into the lower esophageal segment and at the same time lipiodol also passed into the left bronchial tree. Apparently the fistula had reopened. It was thought then that dilatation of the anastomotic site might relieve the partial obstruction and it was hoped that the fistula might close spontaneously. Dilatations were done on two occasions until a No. 5 French catheter could be passed with ease into the stomach. However, the infant continued to aspirate its secretions intermittently as well as the small feedings that were given, until pulmonary infection resulted in death on the twenty-seventh postoperative day.

Autopsy revealed evidence that a small abscess had formed about the anastomotic site with resultant reopening of the tracheal fistula. In addition, there was a second area of stenosis of the lower esophageal segment about 2 cm. distal to the fistulous communication of the esophagus with the trachea. This stenotic area was overlooked at the time of the surgical procedure. The lungs showed evidence of bilateral pneumonia and atelectasis.

CASE 4.—P. T., a full-term female infant, weighing 6 pounds, 13 ounces at birth, was admitted to the University of California Hospital twenty-four hours after birth. Shortly after birth an attack of cyanosis was relieved by aspiration of mucus from the pharynx. It was noted that the child became cyanotic during its first feeding. A catheter was introduced into the esophagus but met an obstruction in the upper third. Physical examination revealed a considerable amount of mucoid material in the pharynx. There were coarse râles throughout both lung fields which cleared somewhat after aspirations of the pharyngeal secretions.

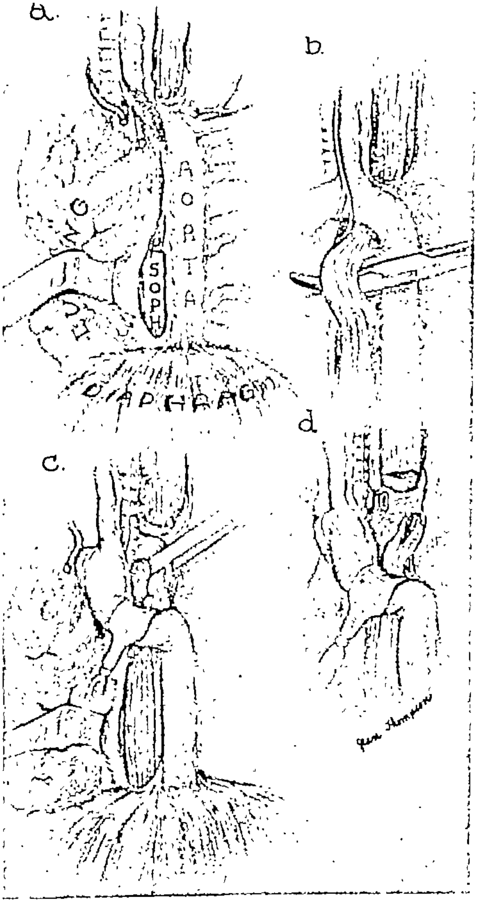

Fig. 2.

Under fluoroscopy the lung fields were clear. A small amount of lipiodol was introduced into the upper esophagus through a small catheter and it demonstrated a blind upper segment ending just above the tracheal bifurcation. During examination, some of the lipiodol was aspirated and it outlined the trachea and main-stem bronchi. A small amount of the lipiodol was seen entering the lower esophagus through a fistulous tract at the bifurcation of the trachea. Gas was present in the gastrointestinal tract.

The infant's dehydration was corrected, the pharyngeal secretions were aspirated frequently, and twelve hours after entry, at the age of 36 hours, the infant was taken to surgery. Under introtracheal ether and oxygen anesthesia, a left transpleural approach was made. Both esophageal segments were mobilized, the lower segment was freed and doubly ligated at the site of the fistula, and end-to-end anastomosis was effected between the esophageal segments. The procedure consumed three hours and twenty minutes. Ninety cubic centimeters of whole blood were given during the operation.

Following the operation, the infant's condition seemed to be good. During the first forty-eight hours the nasopharynx required aspiration at decreasing intervals. After forty-eight hours the infant appeared to be able to swallow all secretions.

Nutrition was maintained with parenteral blood, plasma, saline solution, and glucose. On the seventh postoperative day the child was started on small hourly feedings of from 4 to 6 c.c. of lactic acid formula. Feedings were taken readily so that they were gradually increased daily until a full formula was taken. Thirteen days after operation the wound healed per primam, and the child was discharged twenty-three days after entry. She is now 7 months of age and in excellent condition. She takes fluids readily but purèed foods must be diluted with formula.

The procedure is diagrammatically represented in Fig. 2. The left posterolateral transpleural approach is employed. The pleural space is entered through the bed of the fifth rib. The third and fourth ribs are divided in the paravertebral area. In the case in which the stomach was delivered into the chest it was necessary to divide the sixth rib as well, in order to gain adequate exposure.

The lower esophageal segment is exposed by a short longitudinal incision through the mediastinal pleura just anterior to the descending aorta. By gentle dissection in the posterior mediastinum, the lower esophageal segment is brought into view. In two infants the lower segment was freed for a distance of 4 to 5 cm. below the arch of the aorta in order to help gain as much freedom from tension on the suture line as possible. This procedure did not appear to jeopardize the blood supply of this segment.

The posterior mediastinum superior to the arch of the aorta is entered by dividing the highest intercostal vein and making a longitudinal incision through the pleura just posterior to the subclavian artery. By gentle dissection, the proximal portion of the lower segment can be freed and delivered above the arch of the aorta, using a small hernia tape for traction purposes. The communication with the trachea is interrupted after ligation of the most proximal portion with fine cotton. The closure of the stump of the fistula is further accomplished by placing fine interrupted cotton sutures.

The upper esophageal segment is then freed as far superiorly in the cervical region as possible. A transverse opening is made in the most dependent portion of the upper esophageal segment. A small catheter is then inserted through the lower segment into the stomach to rule out the presence of additional stenotic areas.

Should none exist, the catheter is then withdrawn. A longitudinal incision of comparable length to the transverse opening in the upper segment is made through the anterolateral wall of the lower segment. It is necessary to use a longitudinal incision in the lower segment because of the progressively decreasing diameter of this segment as it approaches its site of communication with the trachea.

The esophageal segments are then anastomosed using two rows of 00000 Deknatel sutures. Interrupted sutures are used to approximate the mucosa. Mattress sutures are used in the second row to approximate the muscularis.

In one infant in which whip sutures were employed, the lumen at the anastomotic site was found to be very small when examined at autopsy.

An attempt is made to relieve tension on the suture line by placing several sutures from the esophageal wall on each side of the anastomosis to the mediastinal tissues. These sutures also serve to prevent traction on the suture line during the act of deglutition.

From our experience with such few cases we are not justified to draw conclusions. All four infants appeared to have withstood the immediate surgery, even though two were premature infants that were exceedingly poor operative risks. One infant died on the twenty-eighth postoperative day, probably because of the presence of a stricture in the lower esophageal segment and which was overlooked at surgery. In this infant a fistulous tract was re-established between the esophagus and the trachea. The last infant had a very uneventful course. She is well at the present time although she may require dilatations in the future.

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DISCUSSION

DR. RICHARD HARWOOD SWEET, Boston, Mass.—There is just one technical matter that I would like to take issue with, namely the technique of tying the esophagus below the tumor and inverting the distal end with a purse string. I have done that several times, under duress, where, because of the poor condition of the patient, I felt it necessary for hastening the operation, but I would like to point out that, at least in my hands, it is very difficult to get an adequate dissection of the pericardial region and the region of the left gastric vessels, which I believe is of great importance if we are going to increase the survival rate in this group.

Might we have the first of three slides which I would like to show to summarize our experience at the Massachusetts General Hospital, which I happened to be reviewing recently?

(Slide.) This represents the experience with 213 patients operated upon with carcinoma of the esophagus, at either the low level, which Dr. Strieder speaks of, involving the cardia, or the high level, in the midthoracic esophagus. Of the latter you can see

DR. CAMERON HAIGHT, Ann Arbor, Mich.—Dr. Holinger should be praised for the superb movies which he has shown to us and for the extraordinarily satisfactory technique he has developed for the moving picture demonstration of lesions seen through an endoscope.

The subject of congenital atresia of the esophagus has greatly interested us at the University of Michigan since Robert Shaw in 1938 first called our attention to the possibility of a direct anastomosis of the two segments of the esophagus. Since then we have stressed the restoration of intrathoracic esophageal continuity whenever possible. In fifty-two patients for whom operation has been performed, we have endeavored to apply this principle, even in some cases in which the chance of success was extremely remote. This policy has been used in preference to the alternate method of the multiple-stage operation with an eventual antethoracic esophagoplasty, because we have not felt justified, up until the present time, at least, in recommending an antethoracic esophageal tube as an eventual means of swallowing for a newborn infant.

Our first use of the principle of esophageal anastomosis was in 1939. During the following two years, we operated upon five patients and were discouraged because all of them died. The sixth patient survived, however, and she happens to be the oldest living patient operated upon by this plan and the first one to have survived following the reconstruction of intrathoracic esophageal continuity. She was admitted at the age of 12 days after having been brought a distance of 500 miles by automobile. Subcutaneous glucose infusions had been given en route to prevent dehydration. There was air in the stomach, a sign which we now know is indicative of a good chance for obtaining a satisfactory esophageal anastomosis. Although there was temporary leakage of the anastomosis with the subsequent development of a stricture, it was necessary to dilate the stricture only on one occasion. The slide shows the roentgen appearance of the esophagus in June, 1946, and also a photograph of the patient at the same time. She is a normal child who enjoys normal activities. There is residual narrowing of the esophagus at the site of the anastomosis, but she is able to eat all kinds of foods, although it is necessary that large food particles be omitted from the diet. As there has been progressive enlargement of the lumen at the site of the stricture, further dilatations have not been needed.

The results that have been obtained during the developmental period of the operation of reconstruction of intrathoracic esophageal continuity are shown in the slide. Fifty-nine cases have been seen during the last eight years. Operation was withheld in seven cases; two of these patients were premature, one of them dying twenty-four hours after admission and the other on the second day after admission. Operation was not used in the remaining five patients because of various anomalies in addition to the esophageal atresia.

Operation was undertaken in fifty-two patients. In eleven of the fifty-two an esophagoesophageal anastomosis was not possible; in another patient it was possible, but not done. In these twelve patients no serious attempt was made to correct the anomaly, with the exception of one recent patient for whom an esophagogastric anastomosis was done by Dr. F. X. Byron.

Of 40 patients for whom an esophageal anastomosis was completed, twenty-two died and eighteen recovered, a recovery rate of 45 per cent. The over-all recovery rate in the fifty-two patients for whom operation was undertaken was 34.6 per cent. If the above results are analyzed in groups according to the years in which the patients were treated, it will be seen that the outlook has changed from one of great pessimism at the beginning to one of considerable optimism at the present time. In the first four years of this study, 1939 to 1943, the recovery rate following esophageal anastomosis was 23 per cent. During the last four years, 1943-1947, the recovery rate following esophageal anastomosis has increased to 55 per cent. All the operations have been done within the brief period of eight years and the refinements in management which will largely influence the results in the future have been used only in recent cases. It appears proper, therefore, to analyze further the results in the more recent cases. Thus, in the last two years there have been ten recoveries following esophageal anastomosis in fifteen cases, and within the last three months six recoveries in six cases. Of these last six cases, three were operated upon by Dr. F. W. O'Donnell, who has the distinction and enviable record of having had a 100 per cent recovery rate to date. We recognize that the nature of the anomaly, the presence at times of associated anomalies and the poor general condition of some of the patients will not allow for 100 per cent recovery of all patients, but the recent results are an index of a figure which can be approximated in the future.

In regard to the type of approach which should be used, we favor the right extrapleural exposure of the anomaly, and particularly if the preoperative roentgenogram demonstrates the presence of air in the stomach, inasmuch as air in the stomach before operation indicates that there will usually be a sufficient length of the two segments to permit the construction of an anastomosis. Thus in forty-four of the fifty-two patients there was air in the stomach before operation and anastomosis was possible in approximately 88 per cent of the forty-four patients. At operation the typical anomaly with a varying degree of separation of the two segments was found in thirty-three of these forty-four cases, and an anastomosis was possible in twenty-eight of the thirty-three. In the remaining eleven of the forty-four patients with air in the stomach before operation, there was partial muscular continuity of the two segments; in this group there was an ample length of the two segments of the esophagus to permit an anastomosis in all cases.

The converse situation is observed when air is not present in the stomach before operation, as was noted in seven of the fifty-two patients. In four of these there was a variable degree of agenesis of the lower esophagus, so that the latter did not extend up to the trachea. An esophago-esophageal anastomosis was obviously impossible because of the short length of the lower segment. In the remaining three of the seven cases, there was a fistulous communication between the trachea and lower esophagus, but the fistula was too small to allow the passage of air. Although an anastomosis was possible in two of these cases, it was unsatisfactory because of the narrow diameter of the lower esophagus.

The excellent opportunity to construct an esophageal anastomosis in patients with air in the stomach, as demonstrated by the above statistics, would indicate that a right extrapleural approach should be favored in this group. In patients without air in the stomach, some other method is needed to obtain recovery in most instances. It would, appear therefore, that in cases without air in the stomach, the left intrapleural approach, which has been used by Dr. Byron in our clinic and recommended today by Dr. Lyon and Dr. Johnson, has great merit, in that it affords an opportunity for the performance of an esophagogastrostomy should an esophago-esophageal anastomosis be impossible, as will usually be the case.

DR. JAMES E. DAILEY, Houston, Texas—For the sake of the record, and because the reported cases of this type of operation are as yet rather small, I should like to offer a small group of only eight cases.

Nine individuals were explored, and resection and anastomosis were performed in eight. One of these operations was done for stricture of the esophagus, two were performed for benign ulcers of the esophagus with marked strictures, one for squamous cell carcinoma and four for adenocarcinoma of the cardia of the stomach extending into the esophagus.

Now if we had stopped with our first five cases, we would have had excellent statistics, as they were 100 per cent recoveries, but the next three died. One of those was a 75-year-old woman with benign ulcers of the esophagus, who died on the third week postoperatively from a peripheral circulatory collapse. An autopsy was performed, and the pathologist could not give us any definite cause of death.

Another of the mortalities was a 71-year-old man, who died twenty-four hours postoperatively, from apparently the same type of circulatory collapse. That was an adenocarcinoma.

The third fatality was a patient 56 years old, who died six weeks postoperatively with an associated empyema.

One of the other patients has since died fourteen months postoperatively from metastasis of the adenocarcinoma to the liver and abdominal organs.

All of these cases were done by the left transthoracic approach. In none of them was it necessary to extend the incision further downward.

I should like to ask Dr. Strieder if he has encountered any troublesome dilatations of the stomach due to sacrificing the vagi.

In all of our cases we have made a habit of not using a Levin tube postoperatively except in two in which we did have some trouble with hugely dilated stomachs. However, the distention disappeared without any further trouble after a few days.

DR. WM. E. ADAMS, Chicago, Ill.—Nine years ago I reported before this association our first case of resection of carcinoma of the lower esophagus. That patient is living and well, without evidence of recurrence today.

Since that time, Dr. Phemister and I have resected approximately sixty cases for this condition, and I would like to report the results on those resections at this time.

During the earlier years, as you all know, the risk of the operation was great for a number of reasons, and our mortality—the same as most—was around 40 per cent. At the time I presented our report nine years ago, the mortality was around 50 to 60 per cent.

You have all heard the statistics given today to show what a marked advance has been made in this short time in the treatment of these lesions. Our over-all mortality in this group of sixty cases is approximately 30 per cent.

In the last year or so, during our last twenty-seven resections, there have been only two deaths. At the present time most of the risk is on a cardiovascular accident basis. There will be an occasional leak, but, as Dr. Strieder has shown us, most of such patients can be brought through with chemotherapy and other means.

I do not quite agree with Dr. Strieder about the mortality being so much greater for the high resection and anastomoses. That certainly has not been true in our hands. I think that is an important factor, too, because so often the lesion is such that we are tempted not to remove enough of the organ, and we are going to have recurrences if we do not make adequate resections.

I also agree with Dr. Sweet, about adequate removal along the cardiac end of the stomach. Our first patient had metastasis to the glands along the lesser curvature of the stomach. If those glands and the tissue in that region are removed, I feel sure that we will have a higher percentage of patients living after a five-year period.

DR. N. LOGAN LEVEN, St. Paul, Minn.—I would like to record my experiences with congenital atresia of the esophagus with tracheoesophageal fistula.

Since 1939, when we had the first successful multiple-stage operation in one of these cases, we have seen forty-two patients with congenital atresia of the esophagus. Of that group there were only three in which no operation was performed. Surgery was refused by the parents of one, one died in the admitting room, and one died twelve hours after admission before any surgery could be carried out.

There were four in which gastrostomy was done as a first procedure. These all died before completion of other procedures. We now know that the primary operation should be within the chest on the fistula, and the gastrostomy, if necessary, may be done as a secondary procedure. There were seventeen patients in which ligation or division of the tracheoesophageal fistula was carried out and the upper blind pouch exteriorized and a gastrostomy performed. Of that group, eleven survived. However, one of these died at the age of 3 years because a gastrostomy tube of large caliber was inserted too far and a perforation of the stomach occurred that was undetected in time for surgery.

We were encouraged by Dr. Haight's first successful primary anastomosis and attempted this procedure. Our first four operations were unsuccessful. The first one was overhydrated with too much saline, and like others we have learned to keep these patients on the dry side. The next three anastomoses leaked, and the tracheoesophageal fistula was reestablished. Since these three cases, we have not encountered this complication of reestablishment of the tracheoesophageal fistula.

Of eighteen patients in which primary anastomosis was carried out, eleven have survived. If we analyze the cases in the past two years, the results have improved considerably.

Twenty-one cases were seen. In two no operation was performed. In five the multiple-stage operation was carried out. Four of these patients are alive and well.

There were fourteen primary anastomoses with twelve successful anastomoses. However, one of these twelve died three months after leaving the hospital of a respiratory infection. This patient had multiple anomalies in addition to the congenital atresia of the esophagus.

I have never encountered a patient where there was a stricture at a point in the esophagus lower than the site of the fistula. This finding is most interesting. I have always passed a catheter into the stomach when I have done an anastomosis. In all of these cases a right-sided extrapleural approach was carried out. I believe that with the extrapleural approach the complications are less severe if there is a leakage at the site of anastomosis. In our department at the University of Minnesota Dr. Vareo also has a 100 per cent record, having operated on two patients with two successful results.

DR. LAWRENCE M. SHEFTS, San Antonio, Texas—I would like to present a case to illustrate some of the technical points that were mentioned concerning carcinoma at the level of the arch of the aorta. The case is that of a 67-year-old man who complained of dysphagia. Barium swallow revealed that the constriction was at the level of the arch of the aorta.

Esophagoscopy revealed that the ulcerating mass started slightly above the superior border of the arch of the aorta. Considering the length of the constriction as seen on the barium swallow, it was evident that with the tumor starting at the superior border of the aortic arch it extended for quite a distance in length along the esophagus. Bronchoscopy revealed that the left main-stem bronchus was pushed slightly forward and slightly to the right. The question arose as to whether or not the left main-stem bronchus was involved in the carcinoma.

In planning an attack on the carcinoma, it was decided that if the left main-stem bronchus were involved and the tumor did not invade the hilar vessels, a left total pneumonectomy would be done along with the necessary surgery on the esophagus.

Fortunately, upon opening the chest, the bronchus came very cleanly off the tumor. In mobilizing the tumor, the first right intercostal artery was torn out of the arch of the aorta. (If one runs into that complication, it can be handled as it was in this case by tying off the first two left intercostals and rotating the arch with the finger on the torn point so that one can reach it to suture it.) The mediastinal pleura was then opened above and below the aortic arch and the enitre esophagus was mobilized, the diaphragm was opened, a clamp was placed across the upper end of the stomach just distal to the cardioesophageal junction, and the esophagus was disconnected from the stomach and brought out over the aortic arch. The upper end of the esophagus was transected above the tumor, the stomach mobilized as has been demonstrated, and anastomosis made anterior to the aortic arch.

In making the anastomosis a circular piece of tissue was removed from the stomach. In spite of this, a very definite stricture resulted which has required considerable dilatation. I am positive that if we had used the technique which Dr. DeBakey described, we would not have had this complication. Dr. DeBakey informed me, after he finished his talk, that since using that particular technique he demonstrated to you in those cases that have gone long enough to ascertain whether or not there would be a possible stenosis, there has been no stenosis.

The first lantern slide shows the typical irregularities noted on barium swallow.

The next lantern slide is a photograph of the specimen and the considerable length of the esophagus which is involved can be readily seen.

The next is a lantern slide with a barium fill-up of the stomach showing the area of anastomosis with the stomach outlined well up above the aortic arch.

The last lantern slide is a photograph of the patient, who is doing quite well.

DR. ALFRED GOLDMAN, Los Angeles, Calif.—I want to take a moment to show a slide and briefly discuss a case that may illustrate the reason why the diagnosis of an esophageal stricture may be made when there is no real stricture.

(Slide.) This is a slide, post mortem, of a baby 5 days old, operated on and dying twenty hours after operation. The death was caused by bilateral pneumonia, which the baby had had two days before the operation.

This slide shows the site of the anastomosis, the operation having been done under a general intratracheal anesthesia. The technique used is that of Gross, using several bites with each suture, tying one over the other to invert the muscularis and thereby bring about the approximation of the mucosa.

The ligated esophageal tracheal fistula is here. It was very difficult to get a catheter all the way in the stomach, and I did not know the reason for that until post mortem.

At this point the esophageal-gastric junction, one sees a very marked thickening in the muscle in the wall of the tube of the lower segment. This muscular hypertrophy is comparable to pyloric stenosis.

I think muscular hypertrophy explains the difficulties in demonstrating the patency of the lower segment, and possibly misdiagnosing it as a stricture.

DR. FRANCIS R. X. BYRON, Ann Arbor, Mich.—I would like to say a few words about those cases with marked hypoplasia of the lower esophageal segment, or with an agenesis of this segment in which the x-ray shows an absence of air in the stomach. I think one is justified in making the presumptive diagnosis of agenesis, and when one combines the x-ray finding with a tracheostomy which shows no fistula between the lower segment and the trachea, one then is justified, I believe, in assuming that the extrapleural direct anastomosis will not be feasible, and that, therefore, a left intrapleural operation and esophagogastrostomy is advisable.

(Slide.) This is a slide that Dr. Haight very kindly loaned to me. There were ten cases in the series at the University of Michigan Hospital in which there was no air in the stomach. Of those, the anatomic defect was proved by operation or autopsy in nine cases. In two of these direct anastomosis of the esophageal segments was possible. In these cases, in spite of the fact that there was no air in the stomach, tracheoesophageal fistula was present, and I think that tracheoscopy is essential to eliminate this possibility.

(Slide.) This baby was admitted at 4 days of age, weighing 5½ pounds. There was no air whatever in his stomach. We elected to do a left transpleural operation.

The upper esophageal segment ended just at the arch of the aorta. It was not mobilized. However, the stomach mobilized readily to reach the level of the aortic arch, so that anastomosis could be made without tension. It does show that the stomach will rise, even in the newborn infant who has never had anything in the stomach.

This is the line of the anastomosis showing excellent healing. This baby lived six days and, to our great disappointment, died late one night. He had had attacks of cyanosis during the postoperative course, and during one of these, the nurse was unable to resuscitate him. The autopsy six days later showed no intrathoracic complications. The anastomosis was nicely healed. What had brought about the baby's death was hypoplasia of both pulmonary arteries with a huge patent ductus arteriosis.

I show this case because it does demonstrate that technically, the operation of esophageal gastrostomy in newborn infants is not only feasible but that that operation is technically much easier than we had anticipated.

DR. W. A. HUDSON, Detroit, Mich.—This is a report on a case that has been reported before this organization previously. It is now approximately eight and one-half years since the patient was operated upon for an extensive carcinoma of the upper third of the esophagus involving also the larynx and upper portion of the trachea.

There was complete resection of the larynx and the first two rings of the trachea, together with the upper third of the esophagus. No attempt was made to reestablish the continuity of the digestive tract. The distal end of the esophagus was attached to the prevertebral fascia in the low cervical region, and the patient has fed herself through a stomach tube passed into the distal portion of the esophagus. She is still alive, and is enjoying good health in spite of the fact that she has been without a larynx or upper third of the esophagus. She travels freely and extensively.

DR. EARLE B. KAY, Cleveland, Ohio.—I would like to discuss briefly the possible advantages of making a tube out of the greater curvature of the stomach for high lesions of the upper thoracic esophagus.

I have had five subtotal esophagectomies where I employed a gastric tube fashioned from the greater curvature of the stomach. To obtain sufficient mobilization of the stomach in high esophagogastric anastomoses it is necessary to ligate the left gastric artery. This supplies the greater portion of the lesser curvature of the stomach. By utilizing the greater curvature half of the stomach in the formation of a tube, the lesser curvature half (that portion devitalized by ligating the left gastric artery) as well as all of the lymph gland-bearing area in this region can be removed. This is a frequent site for metastases. Such a tube will usually reach higher than when the entire stomach is employed. Furthermore, it can be placed in the old esophageal bed underneath the aortic arch. This contributes to less tension on a new anastomosis than when the stomach or gastric tube is brought around the lateral surface of the aortic arch. There is also less tendency to interfere with respiratory function. I would like to inquire as to the type Dr. Strieder employed.

DR. ROBERT R. SHAW, Dallas, Texas. I would like to add a short word about cases of atresia of the esophagus with or without fistula that do not have air in the stomach.

I agree that this usually means a very atresic lower end of the esophagus. However, yesterday morning my associate, Dr. Paulson, operated on one of these patients, and much to his surprise found there was no tracheal fistula, but that the esophagus was intact all the way except for the atresic area, so that it was a very simple matter to open up the esophagus at the point of the atresia and reanastomose the lumen.

I think, however, if a person encounters a case in which there is no air in the stomach or intestines, that it would be wise to make the left-sided approach, even though, in my experience, the right-sided approach is best for most cases, because this would allow the use of the esophageal gastrostomy technique in case the lower end was atresic.

DR. JOHN W. STRIEDER, Boston, Mass.—With regard to gastric dilatation following these operations, in the resectable cases it has not been an outstanding problem with us. However, in some of the inoperable cases, where both vagi have been divided, we have had troublesome dilatation of the stomach.

The remarks of Dr. Adams and Dr. Sweet relative to the resection of the node-bearing areas were, of course, well made. I neglected to say that in these resections we have attempted meticulous dissection of the nodes above and below the diaphragm, the periesophageal nodes and the nodes in the region of the celiac axis. I wish to make it clear that low esophageal cancers are treated like high gastric cancers, namely, with a wide zone of gastric resection.

Regarding the bronchial occlusion which Dr. Kay mentioned, all four of our cases seemed to be definitely due to post-traumatic induration of the bronchus, the tumor having been taken from the region of the stem bronchus, and the endoscopic and x-ray findings were such that it seemed unlikely that it could be due to pressure from dilatation of the stomach. In one autopsied case it was proved not to be due to gastric dilatation.

I neglected to mention, in reporting the patient operated on twice, that, to our mingled feelings of delight and chagrin, a careful histopathological inspection showed no evidence of residual tumor cells.

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BRONCHOSCOPIC AND ESOPHAGOSCOPIC CINEMATOGRAPHY

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THE primary value of taking endoscopic motion pictures is to record the view seen by the endoscopist as he explores the air or food passages and to reproduce it on the screen. Each landmark may be identified in turn before proceeding to advance or withdraw the endoscope. The motion pictures show the endoscopic anatomy and the pathology of the passages; the endoscopic appearance of inflammatory processes, tumors, and foreign bodies also can be shown. Pictures have been made which demonstrate the endoscopic techniques used to remove foreign bodies from the air and food passages, the forceps being shown as they actually grasp the coin, tack, button or other foreign body as it is removed. Motion pictures make it possible to demonstrate the living appearance of the air passages with the characteristic changes caused by normal breathing and the pulsations produced by the heart and near-by large blood vessels. These normal movements are also visualized as they occur in the esophagus. Such normal motility of the structures plays an important part in diagnostic techniques, especially in the air passages, since lack of them may indicate and help identify certain abnormal conditions. Motion pictures help the specialist give students and physicians a working knowledge of endoscopic techniques; knowledge far more complete than that obtained by occasionally looking down an endoscope in the bronchoscopic operating room. A realistic sense of perspective is usually seen in endoscopic motion pictures because of the constantly moving lumen which appears to tip at an angle to the endoscope axis. The procedure of scanning the field, showing successive landmarks each in turn, also contributes to this simulated stereoscopic effect.

DESCRIPTION OF CAMERA

The new endoscopic motion picture camera is similar in some respects to a type previously constructed.[1-4] The light-source, focusing telescope, and camera are combined in one unit (Fig. 1). An attaching clamp at the front of the unit permits the instant attachment or detachment of any of several endoscopes or light-reflecting tubes used to photograph the various areas. A heated removable glass slide placed immediately behind the attaching clamp shields the optical parts as the patient breathes or coughs. The apparatus is held by a built-in handle when photographing through the endoscopes, or supported on a tripod for mirror photography of the larynx. The camera is started and stopped by a trigger lever in the handle which also automatically raises the lamp voltage to the proper color-temperature while the camera is running. The plane of sharp focus at the object is adjustable and may be

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placed at any position from 9 to 26½ inches from the attaching clamp. The telescope and camera are focused simultaneously by a knob on the left side of the housing. The telescope shows an exact duplicate of the film image during finding and focusing as well as while the camera is running. A slot permits the insertion of a supplementary lens for photography of the eardrum at a relatively high magnification.

The following description deals with each portion of the camera separately, to show the basic design and theory underlying its operation.

Endoscopes.—The most obvious choice of open-tube endoscope for photography is one which is blackened on the inside to prevent stray light from fogging the picture, or to prevent reflections from the wall of the scope from being included in the picture. However, experience has shown that it is necessary to use endoscopes whose inner surfaces are brightly polished and nickelplated if sufficient light is to be obtained on the photographic field for taking Kodachrome color pictures. Endoscopes polished on the inside will produce several times the light intensity possible with nonreflecting endoscopes. In a properly designed camera and endoscope, the reflections cause no serious trouble if the finished film is masked with a circular mask to show only the circular field which is visualized through the endoscope. The inner surface of the endoscope near the tip is threaded for a distance of one-half inch which prevents photographing the reflections from this portion of inner surface of the scopes. The out-of-focus images reflected from the remainder of the inner surface are almost completely eliminated by the masking which is described below.

The same endoscope is used both as a bronchoscope and esophagoscope (Fig. 2). It is 16 inches (41 cm.) total length with the free working distance of 11 inches (28 cm.) from the upper teeth. Since the camera lens can be adjusted to photograph at least four inches (10 cm.) beyond the endoscope tip, the total maximum effective free working distance is about 15 inches (38 cm.) for the bronchoscope.

The laryngoscopes are 2½ inches shorter than the bronchoscopes, having 8¼ inches (21 cm.) free working length. This length is more than is necessary for photographing the larynx, but the requirements of the bronchoscopic length determined the focusing range of the lens; this focusing range requires that the laryngoscopes be longer than normal. The camera focus can be adjusted to any point up to 6½ inches (16.5 cm.) beyond the laryngoscope tip. The shorter laryngoscope permits larger pictures on the film than can be made through a tube of bronchoscopic length.

The bronchoscope, small laryngoscope, and esophagoscope are designed to take advantage of a larger diameter of the scope at the upper teeth than that needed to permit introduction into the esophagus or through the larynx. The slightly tapered portion shown increases the light at the tip, compressing the light received to a smaller circle so that sufficient light is obtained at the tip of the scope in spite of its small diameter. Each light ray entering the scope at the large end of the gradual taper is reflected several times before reaching the tip. The steep taper near the attaching flange contributes comparatively little to the total light; it is used to gather the complete cone of rays from the full diameter of the light source.

The endoscopes are heated briefly in the sterilizer just before use, so that moisture from the air passing through them will not condense on the inside bright surface. If any considerable part of the inner surface becomes covered with droplets of moisture, the light reaching the tip is reduced, and underexposure of the color film results.

The endoscopes have a knurled ring immediately in front of the attaching flange, by which they can be held while they are inserted in the recess of the attaching clamp before the clamp is closed. When re-attaching the camera after removing secretions from the field, the ring allows proper alignment of the scope flange, and quick attachment to the camera. A small raised metal knob on each scope indicates the direction of the tip visually or by palpation.

Attaching Clamp.—The attaching clamp permits instant attachment or detachment of any of several endoscopes or light-reflecting tubes. The clamp makes a solid mechanical connection between the endoscopes and camera unit. The endoscope axis is aligned accurately with the camera axis so that the image of the endoscope tip comes in the center of the camera film aperture, and is approximately centered in the mask opening.

Glass Slide.—A heated glass slide is used immediately behind the attaching clamp to shield the optical parts of the camera from gross soiling or condensed moisture. A rectangular opening at one side of the front face of the glass slide allows passage of air through the endoscope to permit the patient to breathe freely when the bronchoscope or direct laryngoscope is used. The glass is optically flat and introduces no aberration into the film image. It is placed at an angle of five degrees to avoid reflections. After the initial heating of the slide, the heat absorbed continuously from the camera lamp bulb keeps the slide warm enough to avoid fogging.

Illuminating System.—An airplane headlight (landing light) bulb is used as the light source in this camera. It was chosen because its two compact filament coils occupy a very small space about 5 mm. square, and because this lamp can be operated on its side instead of in an upright position. The technical description of this airplane tungsten filament lamp is: 240 watt, 12 volt, 20 ampere; medium prefocus base; C-2 type filament; A-19 bulb (2⅜ inches in diameter); total lamp length 4⅛ inches.

The light from this lamp is directed onto the main axis of the camera by means of two condenser lenses and a plane mirror set across the axis at 45 degrees (Fig. 3). The object image returns through a hole in this mirror. A spherical mirror behind the lamp increases the light level and produces more even illumination. An enlarged image of the lamp filament is projected to a plane about 5 inches ahead of the attaching clamp. This is the optimum distance in order to produce the maximum light level through the endoscopes and light-reflecting tubes.

A heat-absorbing glass is used between the condenser lenses to absorb excess heat from the lamp. This is necessary because the heat reaching the tip of the endoscope is slightly greater than the mucosal surfaces can tolerate with safety. An additional heat-absorbing glass is used in the ear-speculum attachment to reduce the heat still further when photographing the eardrum. This second heat-absorbing glass has a hole in the center so that the light to the camera lens does not traverse the glass. Both heat-absorbing glasses are of the new high efficiency type recently announced by the American Optical Company; the glass is nearly colorless and absorbs little light.

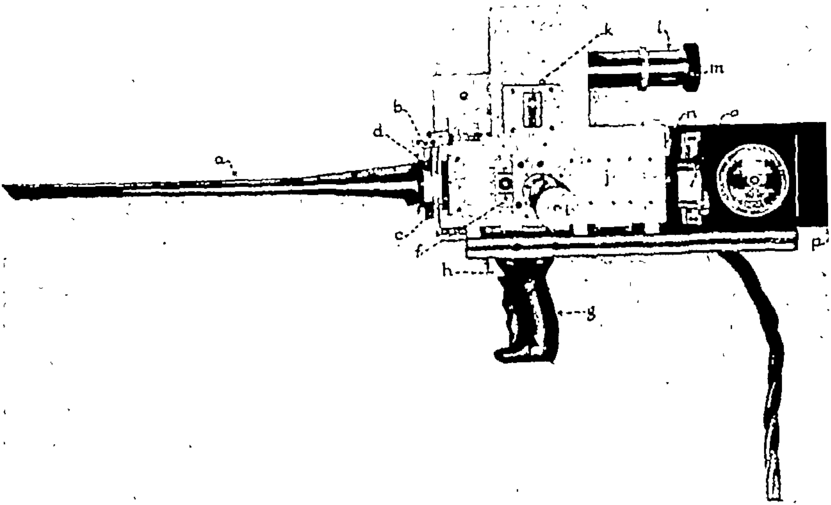

FIG. 1.—Left side view of the camera unit with the bronchoscope attached.

a, Bronchoscope
b, Attaching clamp
c, Opening for breathing
d, Glass slide
e, Lamp house
f, Slot for supplementary lens
g, Handle
h, Trigger
i, Focusing knob
j, Housing for optical system
k, Focus indicator
l, Telescope
m, Eye piece
n, F stop adjusting knob
o, Masking device
p, Bell and Howell autoload 16mm. magazine camera

The lamp is operated at 12 volts while finding and focusing, and is raised automatically to 14½ volts while the pictures are being taken by means of a relay operated by the camera trigger. This produces light of approximately 3450K, the correct color-temperature for type A Kodachrome film. The estimated life of the airplane lamp at 12 volts is about 50 to 100 hours. When operated at 14½ volts, the life is about thirty minutes actual filming time, which permits approximately 750 feet (15 magazines) of film to be taken with one lamp.

A light intensity of about 160 candles-per-square-foot is obtained at the endoscope tip when the lamp is operating at 14½ volts. This corresponds to plane in the object space. The supplementary lens simply shifts both planes of sharp focus a certain distance toward the attaching clamp. With the supplementary lens, the focusing action is basically the same as with the regular endoscopes, but through a shorter distance.

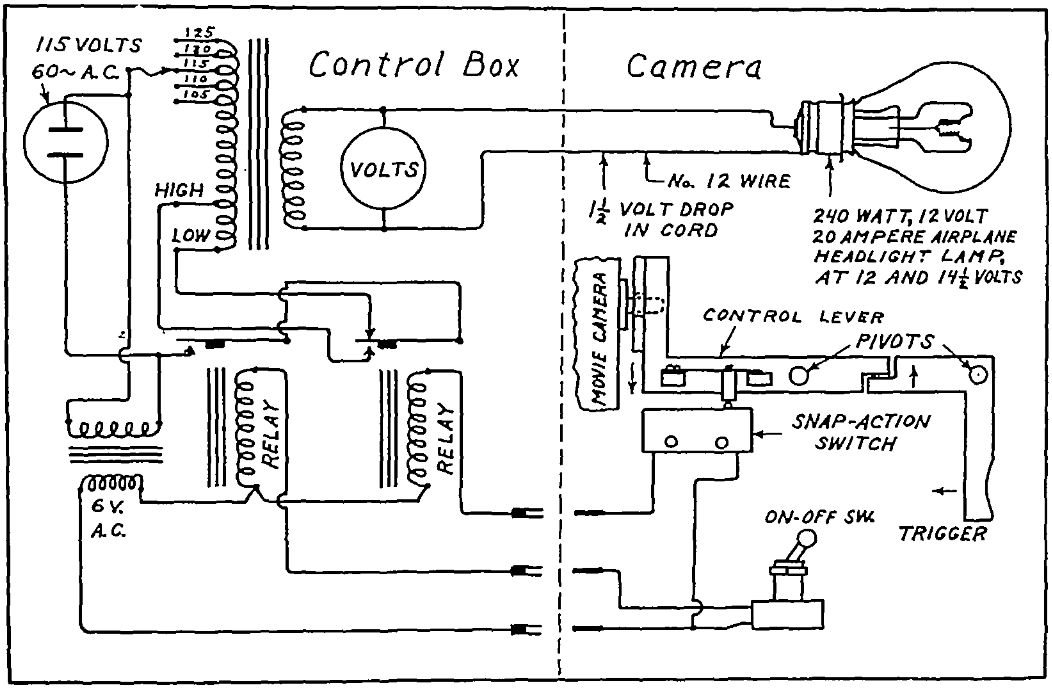

Fig. 4.—Diagram of the electrical system.

Focusing Telescopes.—The focusing telescope is an extremely important part of the camera. By means of the telescope, the field at the endoscope tip is constantly under visual supervision, allowing safe manipulation of the endoscope in order to reach the desired field for photography, or for observation of the field while the endoscope is advanced or withdrawn while filming. The telescope enables the plane of sharp focus for the camera to be placed at any distance beyond the endoscope tip; the plane of sharp focus may be changed while the camera is running. The field is seen at all times, while filming as well as before and after taking the pictures. Experience has shown that the mucosal surfaces of low contrast can be focused upon more accurately by using the aerial image and therefore no ground glass is used at the eye-piece focal plane. The telescope is adjusted to produce correct focus for the camera when the eye is relaxed and focused upon infinity—similar to looking into a microscope. The eye-point is far enough away from the eyecap to permit the operator to wear glasses. The camera is designed for a right-handed person, and for the right eye at the telescope.

The image in the telescope eyepiece is erect and correct from side to side, the same as though the operator were looking directly into an endoscope. The optical system must provide this correct image, since an inverted or transposed image introduces serious risk of trauma when the endoscope is manipulated.

The total magnification of the field as seen in the telescope eyepiece is about five times for the endoscopes, and about ten times for the supplementary lens distance.

A focus indicator is provided in a window at the side of the main housing to show the position of the plane of sharp focus ahead of the attaching clamp. The indicator may be moved by the focusing knob to the position marked on the scale corresponding to the endoscope used. The pre-setting method by means of the indicator is sure and rapid.

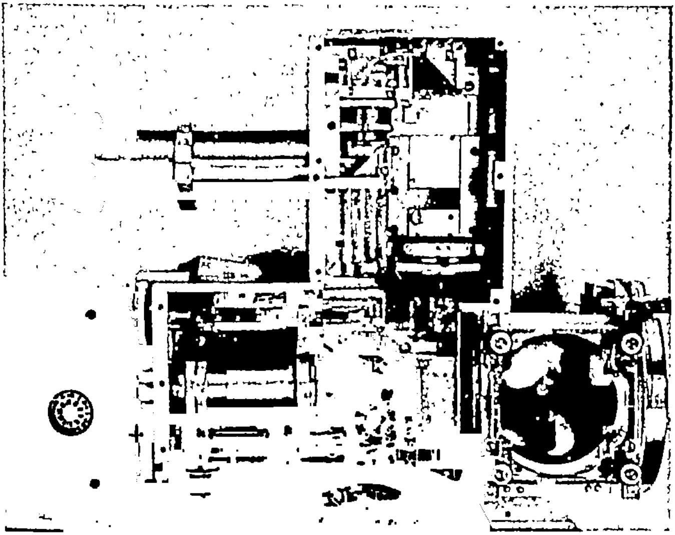

Fig. 5.—Interior of the lens housing viewed from the right side, showing the mechanical arrangement of the paired lenses and the telescope.

Camera Film-Box and Photographic Lens.—The motion picture camera box is a Bell and Howel Auto Load. It is permanently attached to the main housing of the endoscopic camera. The release button is operated by the trigger in the handle. The Auto Load camera uses 16 mm. type A Kodachrome film in 50 foot-pre-threaded magazines and runs about 12½ feet at one winding. This corresponds to 31 seconds of filming time at 16 frames per second. While the normal shutter speed of this camera is 1/43 second at 16 frames per second, the shutter blade opening was increased to allow the light from the lens to remain on the film for a longer period of time, permitting the use of a slightly smaller f. stop. The new shutter speed is 1/34 second. This change is possible because the film image is limited to a circle 0.250 inch in diameter.

The camera model chosen provides for the choice of 8, 16, 24, or 32 frames per second. For bronchoscopic and esophagoscopic photography a speed of 16 frames per second is used at f. 5.6 to f. 6.3. For photography through the laryngoscope a speed of 24 frames per second is used at f. 6.3 to f. 8. The speed of 24 frames per second slows the action of the vocal cords so that their movements seem smoother and more normal in the finished picture.

A special masking device is built into the left side of the camera film box in order to mask off the out-of-focus images reflected from the inside of the endoscopes. The mask is a metal strip with a series of four holes of graduated sizes corresponding to the film image diameter of the various endoscope tips. The largest opening is 0.250 in diameter. The strip is moved by a small knob and the hole selected is centered automatically in the film aperture by a roller which drops into detent notches in the mask strip. The mask is 0.250 inch ahead of the film, and it masks fairly close to the circular film image with only a small margin of the endoscope wall visible in the finished picture. Without such a mask, the bright out-of-focus images reflected from the inside of the endoscopes would distract attention from the circular field of view. With the ear-speculum it is possible to mask down to the exact diameter of the speculum tip.

As previously stated, the camera lens is a 90 mm. focal length f. 4.5 anastigmat type. The maximum usable aperture is f. 5.6. The f. stop is adjusted by a knob at the rear of the main housing, and stops of 5.6, 6.8, 8, 9.5, 11, 13.6 are provided (one-half stop intervals). The maximum circle of confusion on the film, due to aberrations of the lens, is less than 0.001 inch at the film plane. This is entirely adequate for the best quality motion picture photography on 16 mm. Kodachrome film, and is the accepted standard for the best lenses used with 16 mm. cameras.

Depth of Field.—The depth of field (sometimes called depth of focus) at the object plane of sharp focus, is about plus or minus 0.25 inch for a reasonably sharp image. This is for a maximum circle of confusion on the film of 0.004 inch. Theoretically it is possible to show details which are imaged as small as 0.001 inch at the film plane, but 0.002 inch is a good working value for best results. Due to the motion of the screen image, occasional short scenes very slightly out of focus detract little from the general effect. The depth of field values given are adequate and the out-of-focus parts of the image serve to orient the sharp part of the field.

The image on the screen appears slightly enlarged above life size when the pictures are projected. For most of the endoscopic areas the enlargement is about 1.6 life size. This enlargement is based upon the included angle which the image occupies at the eye of the observer. Bronchoscopic pictures are 40 per cent of the screen height, and the large laryngoscopic pictures are 60 per cent. Mirror pictures of the larynx are about 90 per cent of the full height.

Camera Handle.—The camera handle is notched to provide a comfortable and secure grip. The index finger is free to operate the trigger camera release. The handle is located so that the center of gravity of the camera is balanced over the hand when the camera axis is tipped forward to 25 degrees from the horizontal—the approximate angle of the endoscope when the patient is in the recumbent position for direct peroral endoscopy. A threaded hole for a tripod is located in the bottom of the handle to support the camera while taking mirror pictures of the larynx or for taking pictures at the supplementary distance.

TECHNIQUE

The endoscopes are heated to slightly above body temperature by an electric heating pad or by a brief immersion in the sterilizer just before use. They should be thoroughly dried and their inner surfaces polished. Condensed moisture on the inner surface of the endoscope would reduce the reflection of photographic light from the lamp. The glass slide for the camera is heated for about one minute in the top of the lamp-house; the heat from the lamp keeps it warm after it is inserted in the camera slot. A spare glass slide is available should the slide in the camera become spattered if the patient coughs.

The endoscopes may be introduced into the patient with the camera attached, since the lamp and telescope give full visualization of the field at the endoscope tip. The quick-acting attaching clamp for the endoscopes provides instantaneous release of the camera for aspiration of secretions by suction tube if necessary. In order to observe the endoscopic field when the camera is detached, a light carrier from a standard bronchoscope of proper length is placed in the endoscope. Light-carrier canals and suction tubes are not built into the endoscopes since they would encroach upon the circular field and detract from the appearance of the finished film.

While the endoscope is being introduced the plane of sharp focus is set just beyond the endoscope tip. The moving field is photographed to demonstrate the landmarks seen during the introduction of the various instruments. The plane of sharp focus is then set at a suitable distance ahead of the endoscope tip, and the endoscope slowly advanced or withdrawn with the camera running, in order to show the moving field as seen during an endoscopic examination. In this way, it is possible to take a series of scenes fully recording a bronchoscopic examination.

The location of lesions or obstructions in either main bronchus is easily demonstrated by first photographing the coryna and then proceeding down the bronchus to visualize the actual pathology and its position in relation to the principal bronchial orifices. For orientation in showing esophageal pathology, the scene begins with the introduction of the scope through the cricopharyngeus and into the open lumen of the esophagus. The actual lesion is then photographed; a return to the normal lumen completes the scene.

CONCLUSIONS

A review of the foregoing discussion and of the camera description indicates that motion picture photography through the laryngoscope, bronchoscope, and esophagoscope cannot be done satisfactorily by purchasing an "attachment" for a motion picture camera. In fact, an examination of the equipment described in this article will show that the endoscopic motion picture camera consists of a rather complex optical apparatus which combines the light-source, camera lens, and focusing telescope in one unit, and the "motion picture camera'' is used only as the film box. The equipment appears very complex, but it is easier and more convenient to use, and takes better pictures of the endoscopic fields than can be obtained with simpler types of apparatus.

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ESOPHAGEAL HIATAL HERNIAS OF THE SHORT ESOPHAGUS TYPE: ETIOLOGIC AND THERAPEUTIC CONSIDERATIONS

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HERNIATION of the stomach through the esophageal hiatus of the diaphragm has been a subject of great interest in recent years. Improvements in roentgenographic methods have enabled the roentgenologist to recognize this condition with increasing frequency. Although the clinician has become conscious of the frequent occurrence of hiatal hernia and is familiar with the symptom complex which suggests this condition, it remains for the roentgenologist actually to demonstrate the presence of hernia.

In 1926, Akerlund[1] classified esophageal hiatal hernias into three types (Fig. 1). In the first type, the esophagus is of normal length and its lower end is not elevated above the diaphragm, but a portion of the stomach has herniated into the posterior mediastinum beside the esophagus. This type has been called "the para-esophageal hiatal hernia" and is the least common of the three types. In the second type of hernia, the esophagus is of normal length but is elevated above the level of the diaphragm and a portion of the stomach is herniated into the posterior mediastinum. This type is by far the most common form of hiatal hernia and frequently is called the "sliding or gastroesophageal type." Actually, the distinction between these first two types of esophageal hiatal hernia is a matter of academic interest only. The mechanism of their origin differs little and the type of herniation encountered is frequently a matter of degree; the para-esophageal hernias frequently progress to form sliding hernias.[2] Likewise, their management is identical, as both types are amenable to a satisfactory surgical repair.

The third type of hernia is the short esophagus with partial thoracic stomach. There is some question as to whether this condition should be considered a true hiatal hernia. Be that as it may, it is extremely important that the hernia which is associated with a short esophagus be differentiated from the esophageal hiatal hernia which is associated with an esophagus of normal length. The management of the two conditions is entirely different, as surgical replacement of the thoracic portion of the stomach into the abdomen can hardly be accomplished by usual surgical methods when the esophagus is short.

The present paper concerns our experience in 220 cases of patients with short esophagus with partial thoracic stomach who have been seen at the Mayo Clinic in the past eleven years (1935 through 1945). As will be readily apparent, hernia of the short esophagus type presents problems different from those of the usual hiatal hernia. It is of interest that the patients with short esophagus comprise approximately 10 per cent of the total number of patients with hiatal hernia seen in this period.

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PRESENTATION OF DATA

The diagnosis of short esophagus with partial thoracic stomach was made on the basis of roentgenographic findings, esophagoscopic examination, and, in many cases, histologic study of tissue removed at esophagoscopic examination. In many instances the roentgenologic evidence of short esophagus with partial thoracic stomach was indisputable. In 149 of the 220 cases (68 per cent), the diagnosis was confirmed or established by esophagoscopic examination. Difficulty in the differential diagnosis between stricture of the esophagus with and without a partial thoracic stomach was encountered in some cases. In questionable cases, biopsy of the mucosa just below the stricture was taken at esophagoscopic examination for identification of the mucosa. In fifty-two cases of such character, gastric mucosa was recognized at histologic examination. All cases of esophageal stricture of doubtful etiology were excluded from the group.

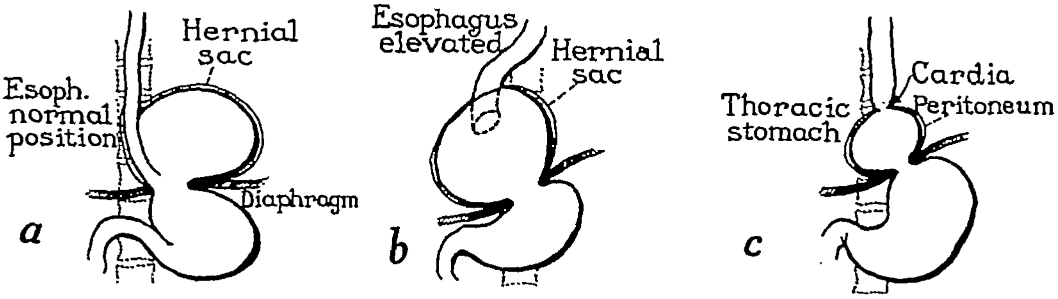

Fig. 1.—Three types of esophageal hiatal hernia; *a*, para-esophageal; *b*, sliding; *c*, short esophagus type.

AGE, SEX, AND OBESITY

Of the 220, 141 (64 per cent) were male and seventy-nine (36 per cent) were female patients. The age of the patients is indicated in Fig. 2. The great majority of patients were in the older age group. In this entire series, 115 patients (52 per cent) were obese at the time of examination or had been obese prior to the development of symptoms of obstruction. On the other hand, twenty-four (11 per cent) were greatly undernourished. These latter also had esophageal obstruction.

SYMPTOMS

The symptoms of esophageal hiatal hernia are many and diverse. Symptoms may be absent or may be severe and disabling. These symptoms may resemble those of any other digestive disturbance or they may present a pattern which suggests the presence of hiatal hernia to the examining physician. Thus, epigastric and substernal distress which occurs after meals and which is intensified when the patient assumes the recumbent position suggests the possibility of hiatal hernia. The distress may be a full feeling, a burning sensation, or pain. It may be referred around the costal margins, into the left side of the thorax, to the scapula, to the neck or arms. The syndrome may simulate the symptom complex of duodenal ulcer, disease of the gall bladder, functional digestive disturbance, intestinal obstruction, or disease of the coronary arteries.

The symptoms of hiatal hernia may be primarily abdominal or thoracic. It is often impossible to distinguish the symptoms of the short esophagus with partial thoracic stomach from those of the paraesophageal or sliding type of hernia. Symptoms referable to the abdomen are much the same in both groups of cases. However, the symptoms arising from the esophagus are particularly significant in cases of short esophagus and have been tabulated in the 220 cases studied in this series (Table I).

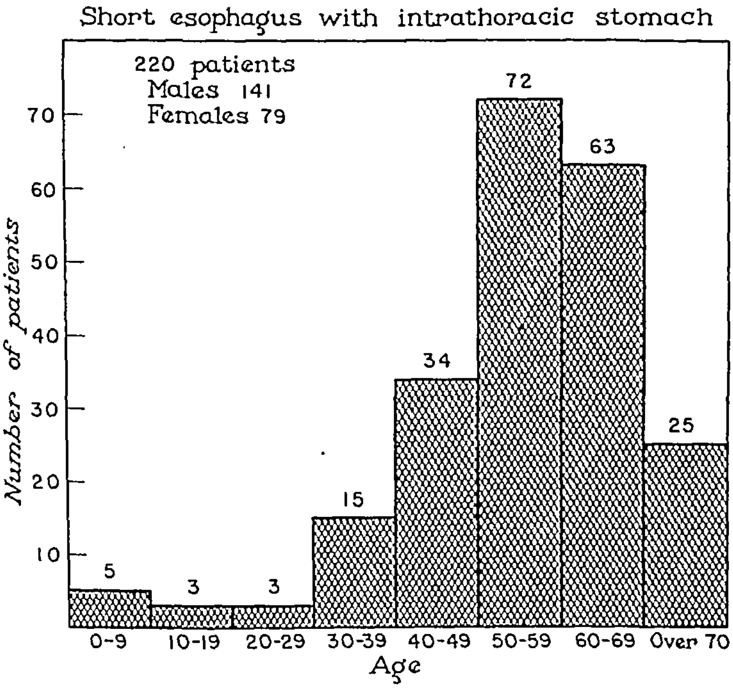

FIG. 2.—Age distribution in cases of short esophagus with partial intrathoracic stomach.

The frequent occurrence of dysphagia is noteworthy. Of the 220 patients, 165 (75 per cent) complained of obstruction to the passage of food on swallowing. In 154 of these patients an actual obstruction was demonstrated, either at esophagoscopic examination or when sounds were passed over a previously swallowed thread. It is of interest that in seventy-six patients, the dysphagia was intermittent or the symptoms of obstruction varied in degree. This observation certainly indicates that spasm of the esophagus plays a definite part in the dysphagia associated with the short esophagus in many cases.

TABLE I. SYMPTOMS REFERABLE TO ESOPHAGUS IN 220 CASES IN SERIES*

SYMPTOM	CASES	
	NUMBER	PER CENT
Obstruction to swallowing	165	75
Substernal distress	71	32
Esophageal pain	20	9
Hemorrhage	18	8
No esophageal symptoms	17	8

*More than one symptom in many cases.

The complaint of substernal burning or distress was noted in seventy-one cases. This symptom was frequently described on the charts as "sour belching" or "acid regurgitation," and patients complained of the burning sensation most often after going to bed. Actual substernal pain was described by twenty patients in the series. In some instances the pain was referred to the neck, shoulders, or arms and had to be distinguished from the pain of cardiac disease. Eighteen patients who did not give any evidence of duodenal or gastric ulcer had had gross hemorrhages. Adequate explanation for hemorrhage from the esophagus usually could be demonstrated at esophagoscopic examination.

ROENTGENOLOGIC DIAGNOSIS

The technique of performing roentgenoscopic examination of the esophagus and stomach in cases of esophageal hiatal hernia has been described by Harrington and Kirklin.[3] The roentgenologic diagnosis of hiatal hernia is exceedingly accurate and is indispensable to the recognition of this condition. In the case of the short esophagus with partial thoracic stomach, special problems are introduced because of the frequency of stenosis of the lower part of the esophagus or associated esophageal spasm. In a number of instances the roentgenologist has requested an esophagoscopic examination to clarify the situation. However, the roentgenologist is able to demonstrate the gastric rugae in the supradiaphragmatic portion of the stomach and to distinguish the intrathoracic part of the stomach from the normal ampulla of the esophagus. The roentgenoscopic diagnoses of our 220 patients are listed in Table II. In 182 of these patients the amount of stomach above the diaphragm was estimated. In 35 per cent there were 2 inches (5 cm.) or less of stomach above the diaphragm. From 2 to 4 inches (5 to 10 cm.) of stomach were visible above the hiatus in 53 per cent, and more than 4 inches (10 cm.) of stomach were intrathoracic in 12 per cent.

TABLE II. ROENTGENOSCOPIC DIAGNOSIS IN CASES OF SHORT ESOPHAGUS (1935 THROUGH 1946)

DIAGNOSIS	CASES
Short esophagus	133
Hiatal hernia	46*
Stricture of lower part of esophagus	30
Esophageal spasm	7
Carcinoma (associated with hernia)	3
Indeterminate	1
Total	220

*In the early years covered by this investigation, no effort was made to determine the type of hernia.

ESOPHAGOSCOPIC FINDINGS

Esophagoscopy was performed in 149 (68 per cent) of the 220 patients. Examinations were performed once in 125, twice in eighteen, three times in four, and four times in two patients. In 126 of the 149 patients on whom esophagoscopy was carried out, the distance from the upper incisor teeth to the esophagogastric junction was measured at the time of esophagoscopy. This distance was 14 inches (35.6 cm.) or more in 36 per cent, and less than 14 inches in 64 per cent. Inasmuch as the distance from the upper incisor teeth to the esophagogastric junction at the diaphragm is approximately 16 inches (40.6 cm.) in the average normal adult, it is evident that the esophagoscopist and the roentgenologist agreed closely in their estimations of the amount of stomach in the thorax.

The presence or absence of ulceration was noted in all cases. Significant ulceration was reported in eighty-nine patients (60 per cent), slight ulceration in twelve (8 per cent) and no ulceration in forty-seven (32 per cent). At the time of esophagoscopy evidence of diffuse ulcerative esophagitis was found in twenty-two (15 per cent).

Specimens of tissue were taken for microscopic examination in eighty-six patients. In many cases esophageal stricture was present and tissue was removed in order to determine the type of mucosa immediately below the obstruction. In fifty-two patients gastric mucosa was demonstrated at histologic examination to prove that a short esophagus was present. In thirty-four biopsy was carried out to exclude malignant disease. In three patients carcinoma was found in association with a short esophagus and partial thoracic stomach. Two of these carcinomas were gastric in origin; the other was a squamous cell lesion. From thirty-one patients inflammatory tissue was obtained. Adenocarcinoma occurring in the herniated portion of the stomach was revealed at transthoracic exploratory operation in one additional case in the series.

Thus it is seen that esophagoscopic examination is extremely important in the diagnosis of the short esophagus with partial thoracic stomach. Esophagoscopy may be necessary to determine the type of hiatal hernia that is present. This is particularly important inasmuch as a patient who has a short esophagus is not a favorable subject for surgical treatment. Biopsy of mucosa from around a stricture is not only desirable in the exclusion of malignant disease, but also is valuable to provide the distinction between cicatricial stricture of the esophagus and stricture associated with short esophagus and partial thoracic stomach. It is our policy to perform esophagoscopic examination in all cases of hiatal hernia in which surgical repair is contemplated and particularly in those cases in which dysphagia or evidence of esophageal obstruction is noted.

In our experience, esophagoscopic examinations are performed most satisfactorily with the aid of both topical and general anesthesia. After the throat is prepared by topical application of a solution of 20 per cent cocaine to the piriform sinuses, the patient is anesthetized with Pentothal Sodium, administered intravenously. In a patient who has a short esophagus, the esophagus is found to be a straight tube without tortuosity or redundancy. The normal deviation of the lower part of the esophagus anteriorly and to the left is absent. If organic stenosis is not present, the esophagogastric junction is usually found to be open; the normal sphincteric action of the cardia is not encountered, and there is often a free flow of gastric secretions into the esophagus (incompetent cardiac sphincter). Shortness of the esophagus may be demonstrated by actual measurement also.

ETIOLOGY OF THE SHORT ESOPHAGUS

For many years the term "congenital short esophagus" has been used to designate the condition which we are describing.[4-7] In fact, in early articles dealing with the subject, the congenital origin of the condition was taken for granted. In Jackson's early report[8] on this subject and peptic ulceration of the esophagus, the short esophagus was assumed to be congenital. As recently as 1942, Dick and Hurst[4] stoutly defended the conception of a congenital short esophagus. In 1938 Moersch[9] stated that the picture of short esophagus "occurring as a result of cicatrization of the esophagus cannot be dismissed." Allison, Johnstone, and Royce[10-12] have presented evidence to prove that the short esophagus is caused by peptic ulceration of the esophagus followed by healing and contraction.

The basic embryologic and anatomic considerations which concern the esophagus, the stomach, and the esophageal hiatus of the diaphragm have been reported in detail by one of us (S. W. H.)[2, 3, 13, 14] in previous communications. The facts brought out have great bearing on the development of all esophageal hiatal hernias. In brief it should be recalled that the formation of the diaphragm in embryologic life coincides with the descent of the stomach from its thoracic position. The esophageal hiatus is formed by the closure of the diaphragm about the lower end of the esophagus. If the descent of the stomach is delayed, the esophageal hiatus will form about the cardiac end of the stomach. Thus the esophageal hiatus will be abnormally large. In a few instances no further descent of the stomach will occur and the result will be a true congenital short esophagus with partial thoracic stomach. However, in most instances the stomach will continue its descent into the abdomen, thus producing an esophagus of normal length but leaving an esophageal hiatus that is large or incompetent.

The enlarged esophageal hiatus is the probable basis for the development of all types of esophageal hiatal hernias. The frequency with which an enlarged esophageal hiatus can be demonstrated in the course of other abdominal operations has been emphasized by one of us (S. W. H.).[13] The diaphragmatico-esophageal membrane, consisting of elastic and fibrous tissue originating in the fascial coverings of the diaphragm, is the only structure fixing the diaphragm to the lower part of the esophagus. In the presence of an enlarged hiatus, this membrane is hardly strong enough to withstand a traction effect from the esophagus or a pulsion effect from increased intra-abdominal pressure.

All thoracic surgeons are aware of the extreme elasticity of the esophagus. In this connection, the recent studies of Dey, Gilbert, Trump, and Roskelley[15] are of great interest. They found that stimulation of the vagus nerve in dogs resulted in reflex shortening of the esophagus. The stimulation of the vagus could be a direct electrical impulse or could be indirect, such as would be produced by distention of the gall bladder or manipulation of the liver, stomach, or other viscera. If the thorax in the dog was closed, stimulation brought the stomach up to the hiatus but not into the thorax. If the thorax was opened, the shortening of the esophagus drew the stomach into the thorax. That spasm plays a definite part in shortening of the esophagus, especially in the early phases of the condition, is a fact that has been emphasized by Johnstone,[12] by Smithers[10] and by one of us (S. W. H.).[14] From the work of Dey and his associates,[15] one can infer that associated disease of the upper abdominal organs may be responsible for the spasm and reflex shortening of the esophagus.

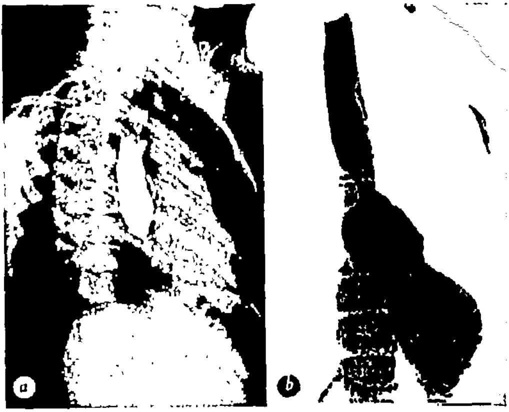

Fig. 3.—Congenital short esophagus with stricture in a boy aged 6 years in 1932 who had had dysphagia since birth. Symptoms have been controlled by dilatations since 1932: *a*, esophagus and stomach in 1932; *b*, in 1945.

Congenital Short Esophagus.—The 220 cases of short esophagus which are the basis of this report were studied carefully from the standpoint of etiology (Table III). Patients who gave a history of dysphagia from birth or early childhood were considered to have a true "congenital short esophagus." There were nine (4 per cent) such patients. Their ages varied from 3 to thirty-six years. Five of them were less than 10 years of age at the time they were first seen at the clinic, two were between 10 and 19 years of age, and two were 35 and 36 years of age, respectively. None of these patients gave any history of ingestion of lye or other caustic poisons. All nine had smooth strictures at the esophagogastric juncture without evidence of ulceration. All were treated successfully at the clinic or elsewhere by means of dilatations performed over previously swallowed threads (Fig. 3).

Why all the patients who had true congenital shortening of the esophagus had associated strictures is a question that is difficult to answer. These cases are similar to the series reported by Findlay and Kelly[5] and Manges and Clerf.[6] Obviously, the presence of esophageal stenosis permitted an early recognition of the condition, and it is conceivable that true congenital shortening of the esophagus has escaped detection in other cases because of the absence of any symptoms.

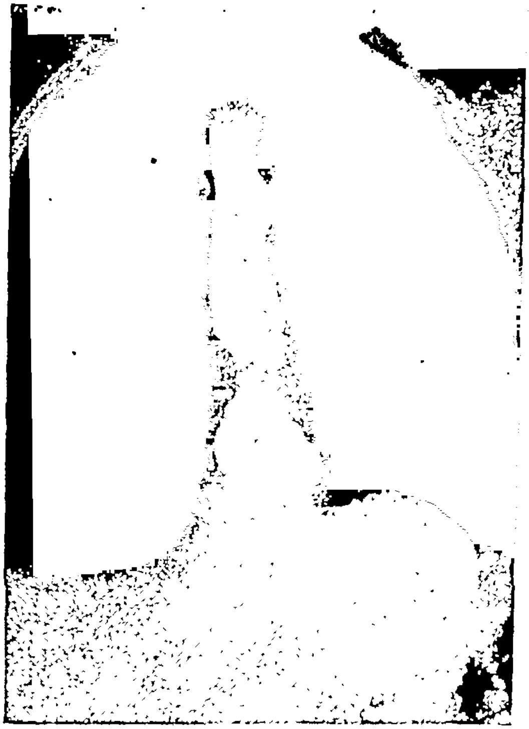

Fig. 4.—Hiatal hernia of short esophagus type of "indeterminate" etiology in a woman aged 55 years who had had dysphagia for three years without other symptoms. Esophagoscopy revealed a smooth stricture with foreign body (kernel of corn). Dilatations to the size of a 45 F. sound were done on two occasions two years apart.

Short Esophagus of Indeterminate Etiology.—The next group of patients to be considered are those who presented the picture of short esophagus without any obvious etiologic basis. There were forty patients (18 per cent) with shortening of the esophagus of indeterminate etiology. Five of these forty patients, all between 45 and 60 years of age, had no symptoms referable to the gastrointestinal tract. Roentgenologic studies of the esophagus and stomach had been performed at the patients' request. Although no endoscopic studies were done on these five patients, the roentgenologist's diagnosis of short esophagus was definite. The other thirty-five patients in the group in which the etiology was indeterminate came to the clinic complaining of difficulty in swallowing of recent origin but had no other symptoms or history of digestive difficulty (Fig. 4). Facts concerning this group of patients are presented in Tables III and IV. We do not believe that these patients had true congenital, short esophagus. It is obvious that the diagnosis was made at

TABLE III. ETIOLOGY OF SHORT ESOPHAGUS WITH PARTIAL THORACIC STOMACH IN 220 CASES

ETIOLOGY		CASES	TOTAL CASES	PER CENT
I. Congenital: dysphagia since birth			9	4
II. Indeterminate etiology			40	18
A. No digestive symptoms; "accidental finding"		5		
B. Dysphagia: onset late in life and only symptom		35		
III. Acquired etiology			171	78
A. Excessive vomiting		36		
B. Esophagitis associated with hiatal hernia of para-esophageal or sliding type		63		
1. Operative repair	17			
2. Other cases	46			
C. Long-standing digestive distress		57		
1. Duodenal ulcer (without obstruction)	18			
2. Unclassified dyspepsia	39			
D. Scleroderma (acrosclerosis)		9		
E. Antecedent cardiospasm		2		
F. Carcinoma occurring in hernia		4		

TABLE IV. SHORT ESOPHAGUS OF INDETERMINATE ETIOLOGY: DATA CONCERNING THIRTY-FIVE CASES IN WHICH DYSPHAGIA WAS THE ONLY SYMPTOM

AGE (YR.)	CASES	AVERAGE DURATION DYSPHAGIA (YR.)	NATURE OF OBSTRUCTION	
			STRICTURE	SPASM
More than 70	*10*	*4.3*	8	2
60-69	13	5.8	8	5
37-59	12	3.6	8	4

a fairly advanced age in this group and that dysphagia developed late in life. This is certainly difficult to explain. However, it is probable that a congenital enlargement of the esophageal hiatus of the diaphragm was present and that atrophy of the diaphragmatico-esophageal membrane took place as these patients grew older.

In many of these cases, the history suggests that esophageal spasm precedes the development of organic stenosis. It seems likely that cardioesophageal relaxation described by Robins and Jankelson,[17] and more recently by Berk,[18] is closely associated with the incompetent or enlarged esophageal hiatus. In cardioesophageal relaxation, the physiologic sphincter at the cardia is incompetent and gastric secretions regurgitate freely into the lower part of the esophagus. We have observed incompetence of this sphincter many times at esophagoscopic examination. As Robins and Jankelson pointed out, the symptom of "heartburn" is not necessarily associated with cardioesophageal relaxation.

Although the etiologic factor in the cases in this group has been labeled as "indeterminate," it is conceivable that a combination of hiatus insufficiency, atrophy of the diaphragmatico-esophageal membrane, spasm of the esophagus, incompetence of the cardiac sphincter, and, finally, ulcerative esophagitis may have produced the end result. The patients probably had an esophageal hiatal hernia of long standing which produced few or no symptoms until cicatrization of the lower part of the esophagus gave obstructive symptoms.

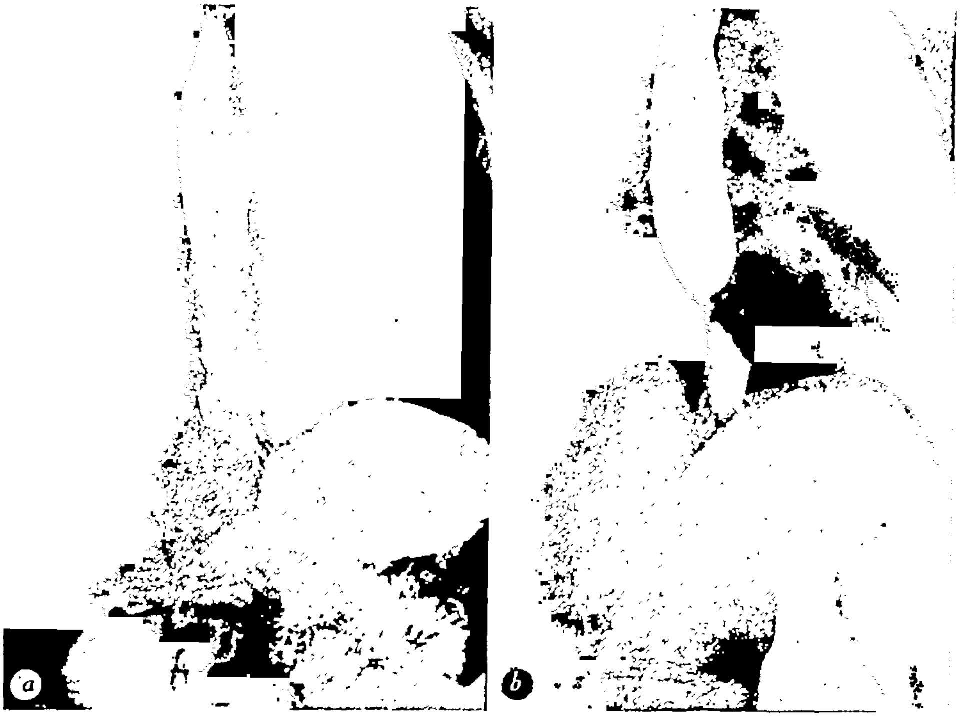

Fig. 5.—Hiatal hernia of acquired short esophagus type due to duodenal ulcer with obstruction in a man aged 58 years who had had epigastric distress for fifteen years but no dysphagia. Esophagoscopy revealed severe esophagitis with ulceration. Ulcer therapy was instituted. In three months marked dysphagia required dilatation and later pyloric obstruction with vomiting and marked esophageal obstruction developed. Gastroenterostomy was performed and stricture at esophagogastric junction dilated three years after initial visit: *a*, 1940, *b*, 1943.

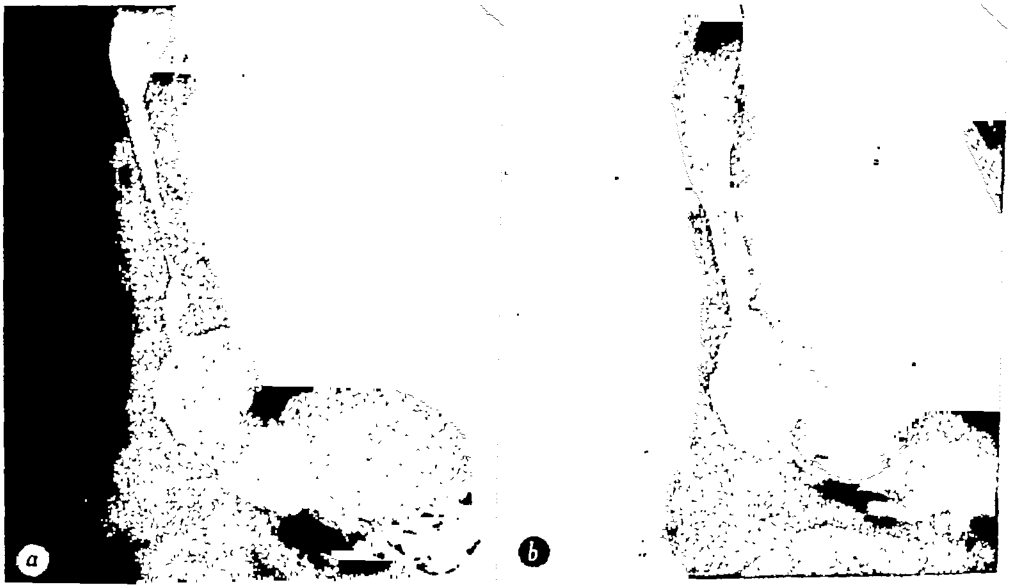

Fig. 6.—Short esophagus with partial thoracic stomach and stricture at esophagogastric juncture, both acquired after resection of the colon for carcinoma, in a man aged 73 years. There was intestinal obstruction with vomiting for two months before operation. Dysphagia (nasal tube had been used) developed two months after operation. Esophagoscopy revealed severe ulceration, esophagospasm, and stricture. Dilatations were needed once a month for relief of dysphagia: *a*, November, 1946, severe ulceration, spasm, and stricture; *b*, March, 1947, after dilatation.

Acquired Short Esophagus.—Of the 220 cases of short esophagus with partial thoracic stomach, there was an apparent etiologic factor in 171 (78 per cent). These cases may be divided into several groups. In the first group the patients gave a history of excessive vomiting. Of the thirty-six patients in this group, nineteen had obstructive duodenal ulcers (Fig. 5), seven had vomiting associated with various surgical conditions (Fig. 6), two had vomiting of pregnancy, one vomited because of a brain tumor, one had frequent bouts of migraine with vomiting, and six vomited as part of a syndrome of dyspepsia or gall bladder disease (Fig. 7). In this group, the stenosis of the lower part of the esophagus was often pronounced and a number of these patients came to us with almost complete esophageal obstruction.

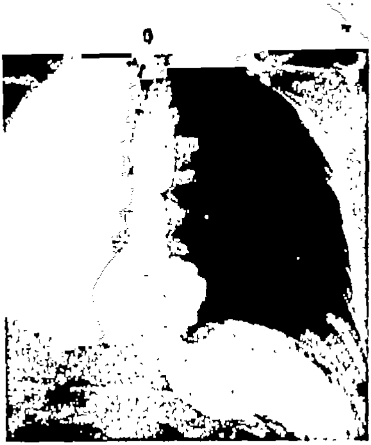

Fig. 7.—Hiatal hernia with short esophagus of acquired type due to gallstones and vomiting in a woman aged 63 years who had had substernal burning and regurgitation of sour fluid for ten years and dysphagia for four years. At esophagoscopy obstruction and ulceration was demonstrated 8⅝ inches (21.8 cm.) from upper incisor teeth. Biopsy revealed gastric mucous membrane. Periodic dilatations were carried out.

In the second group of acquired short esophagus there were sixty-three cases (Table III). These patients gave histories and had signs which suggested that an esophageal hiatal hernia of the paraesophageal or sliding type had been present for a considerable time. Characteristically, these patients had experienced epigastric and substernal distress which was made worse by lying down. In this group of cases, it was felt that esophagitis and recurring ulceration of the lower part of the esophagus had resulted in cicatrization and shortening of the esophagus (Fig. 8). Seventeen of these sixty-three patients had had operations for repair of hiatal hernia. In these seventeen patients, temporary interruption of the left phrenic nerve was followed by abdominal operation with replacement of the herniated stomach into the abdomen. In some of these cases shortening of the esophagus was noted at operation. In others, shortening apparently took place as a result of esophagitis after operation (Fig. 9). The operative cases will be discussed later under treatment.

It is of interest that twenty-three of the 220 patients in our series had gall bladder disease, in addition to the short esophagus with partial thoracic stomach. Also, thirty-two patients gave a history of significant surgical procedures on the upper part of the abdomen exclusive of repair of hiatal hernia.

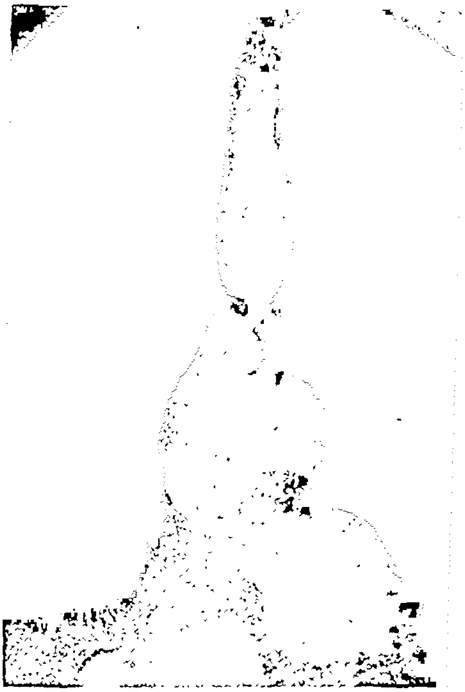

Fig. 8.—Hiatal hernia of short esophagus type in a woman aged 61 years. Diagnosis of large esophageal hiatal hernia had been made ten years previously. Dysphagia was present one year only. At esophagoscopy, marked esophagitis and ulceration were present. Stricture and gastric mucous membrane were 12½ inches (31.8 cm.) from margin of the upper teeth. Relief of dysphagia was by dilatation.

In fifty-seven cases (Table III) the patients gave a history of upper abdominal of long duration. Eighteen of these patients had duodenal ulcers without evidence of pyloric obstruction. The remainder had epigastric distress which was not suggestive of esophageal hiatal hernia.

In nine patients in this series (Table III) a short esophagus with partial thoracic stomach was associated with scleroderma (acrosclerosis) (Fig. 10). The esophageal lesions of scleroderma have been reported by O'Leary, Kirklin, and one of us (A. M. O.).[19] Involvement of the esophageal wall by the sclerodermatous process is apparently responsible for the shortening of the esophagus in this group.

In two cases the short esophagus apparently developed secondary to cardiospasm (Table III). One of these patients, a man 57 years of age, had had dysphagia for twenty-four years. He was seen periodically at the clinic for twelve years before roentgenologic evidence of shortening of the esophagus developed. The other patient, a woman 61 years of age, had both cardiospasm and hiatal hernia in 1941 and on her return in 1944 was found to have a short esophagus.

Four patients were seen who had carcinoma associated with short esophagus (Table III). In three of these patients the carcinoma was gastric in origin (Fig. 11). The fourth patient had a squamous cell carcinoma. Attention is called to previous similar reports by Christiansen,[20] Raven[21] and Smithers,[14] of coexisting carcinoma and hiatal hernia.

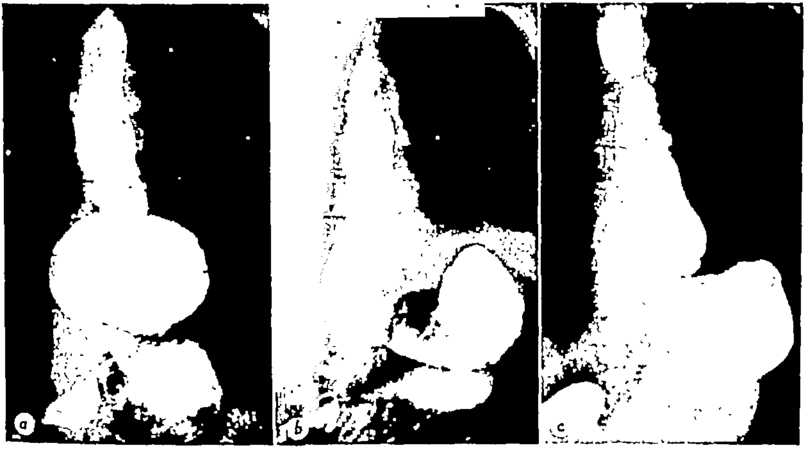

Fig. 9.—Esophageal hiatal hernia with acquired short esophagus due to esophagitis, in a woman aged 60 years who had had epigastric distress for twenty-eight years but no dysphagia; esophagoscopy revealed esophagitis with ulceration at esophagogastric junction 12 inches (30.5 cm.) from the upper incisor teeth. There was a peptic ulcer seen on the left border of the esophagus. *a*, Before temporary left phrenic interruption with repair of hernia; *b*, after operation; *c*, thirty months after operation. Dysphagia had developed. Esophagoscopy revealed stricture 9 inches (22.9 cm.) from margin of upper teeth. Biopsy from region of stricture revealed gastric mucous membrane. Dilatation relieved dysphagia.

Comment.—As has been pointed out previously by one of us (S. W. H.), the evidence indicates that true congenital short esophagus is rare. It occurred in 4 per cent of our group. The congenital factor which appears to play a part in the development of all hiatal hernias is congenital enlargement of the esophageal hiatus of the diaphragm (Table V). Weakening or disruption of the diaphragmatico-esophageal membrane is also necessary for the development of hernia. Atrophy of this membrane apparently occurs in older persons. Increased intra-abdominal pressure, especially that associated with obesity, plays a part in the development of hiatal hernias.

It is reasonably well established that the short esophagus may be caused by severe esophagitis and ulceration of the lower part of the esophagus followed by healing and cicatrization.[10, 11, 16, 22] This is best illustrated by cases of excessive vomiting in which shortening of the esophagus resulted. Acid however, progressive esophagitis resulted in shortening of the esophagus after an apparent successful repair (Fig. 9).

Clark and Adams[23] described the procedure for transthoracic esophagogastrostomy, which they have employed in cases of benign stricture of the esophagus. This procedure consists in making an anastomosis between the fundus of the stomach and the esophagus above the stricture. This procedure might be employed in cases of short esophagus in which the stricture cannot be dilated satisfactorily.

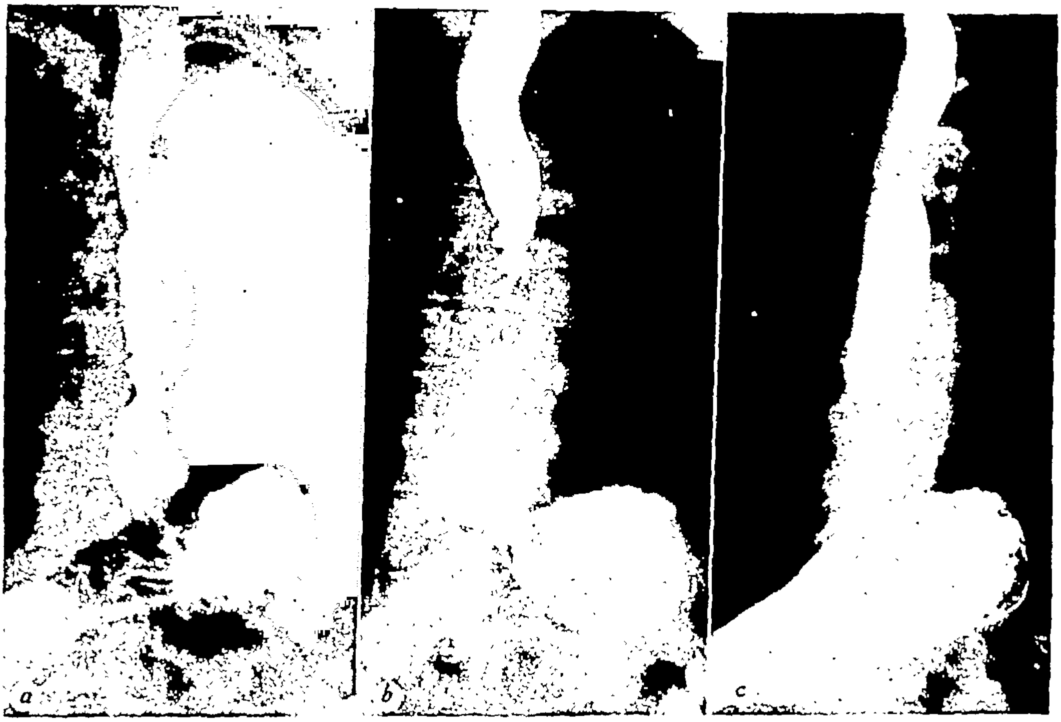

Fig. 12.—Hiatal hernia with acquired short esophagus in a man aged 71 years who had had substernal distress and dysphagia for eighteen months. Esophagoscopy revealed ulceration, and biopsy revealed gastric mucosa. *a*, Ulceration; *b*, spasm played large part; *c*, moderate obstruction to sounds at recent visit three years later.

The most common symptom demanding treatment in the 220 cases was dysphagia. In our experience, dysphagia has been treated most satisfactorily by dilatations performed over a previously swallowed thread. In patients whose dysphagia is caused by spasm, dilatation with a 50 F. sound can be accomplished with ease. However, in the great majority of instances, organic stenosis is present and graduated sounds up to 45 F. must be used. Because of the cicatricial nature of the stenosis, dilatation must be repeated from time to time. Dilatations were performed in 145 of our 220 cases (Table VI). In about half of these only one series of dilatations was carried out at the clinic. In some of the cases twenty or thirty dilatations were necessary in a period of years.

In the early phases of treatment of patients with organic stenosis, dilatations must be carried out every few weeks. However, it usually is possible to increase the intervals between dilatations up to six months or more.

TABLE VI. TREATMENT

TREATMENT		CASES
Interruption of phrenic nerve and surgical repair		17
Interruption of phrenic nerve only		4
Dilatation of stricture		145
Dilated once	79	
Dilated twice	23	
Dilated three times	14	
Dilated four times or more	29	

On the whole, the results of treating these strictures with dilating sounds have been satisfactory. Most of the patients are able to eat almost normally. The risk of performing dilatations in this group by the method described is small. We have had no fatalities resulting from dilatation in these cases. Dilatation should never be done by blind bougienage.[24, 25]

Medical treatment is directed against the further development of ulceration in the esophagus. In the presence of ulcerative esophagitis, a bland type of diet such as that employed in peptic ulcer is desirable. The frequent use of antacid preparations will keep gastric secretions neutralized. For patients who are overweight, a reduction program is imperative. It is amazing how often symptoms of hiatal hernia can be controlled by keeping the weight down and reducing the intra-abdominal pressure. Elevation of the head of the patient's bed is a valuable aid. The head of the bed should be raised 12 to 15 inches (30 to 38 cm.) above the foot. This procedure tends to prevent regurgitation of secretions into the esophagus during the night.

Admittedly, the management of short esophagus with a partial thoracic stomach is not as satisfactory as the surgical repair of the other types of diaphragmatic hernia. However, the majority of patients who have a short esophagus can live comfortably if they will follow the regimen outlined and report for dilatations when necessary.

SUMMARY

A study of 220 cases of short esophagus with partial thoracic stomach was made. On the basis of this review, the following conclusions may be drawn and observations made:

True congenital short esophagus is rare (4 per cent of the cases in our series). In an overwhelming majority of the cases shortening of the esophagus is acquired in later years of the patient's life.

Basic anatomic factors in the development of hiatal hernia are congenital enlargement of the esophageal hiatus of the diaphragm and atrophy or weakness of the diaphragmatico-esophageal membrane.

Shortening of the esophagus develops as a result of "peptic" ulceration of the esophagus. Peptic ulceration of the esophagus may be the result of (1) excessive or prolonged vomiting, or (2) incompetence of the physiologic sphincter at the cardia, when it occurs in association with hiatal hernia or with reflex spasm of the lower part of the esophagus. Reflex spasm of the esophagus in the result of stimulation of the vagus nerve and may be produced by a variety of digestive disorders.

Dysphagia is the most common symptom associated with the short esophagus. In early stages, spasm may be the cause of dysphagia. However, organic stenosis of the lower part of the esophagus develops in most cases.

Hiatal hernia of the short esophagus type is not favorable for surgical treatment. When dysphagia is present, dilatation may be carried out by passing sounds over a previously swallowed thread. Medical measures are directed against further ulceration of the lower part of the esophagus.

Because the treatment of short esophagus type of hernia is radically different from that of the usual hiatal hernia, it is important that an accurate diagnosis be made. Careful roentgenoscopic studies are necessary and esophagoscopic examination is frequently required if hiatal hernias of the short esophagus type are to be differentiated from hiatal hernias with esophagus of normal length.

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DISCUSSION

DR. STUART W. HARRINGTON, Rochester, Minn.—This study of 220 cases of short esophagus with elevation or herniation of the stomach through the esophageal hiatus was made to obtain criteria for the establishment of the clinical diagnosis and classification of the different types that occur. These data are essential in order that those types that are most effectively treated by conservative measures and dilatation can be distinguished from those that demand surgical treatment as well as from those that require both dilatation and surgical intervention.

I have been chiefly interested in the types of short esophagus that do not respond to conservative management, and in which surgical treatment has to be considered. I would like to emphasize some of the important points made in this presentation: (1) that dysphagia and hemorrhage in cases of esophageal hiatus hernia usually indicate a complicating lesion of the esophagus that must be carefully investigated before surgical treatment is instituted, and (2) that roentgenographic studies may not reveal an associated lesion of the lower part of the esophagus because the lesion may be obscured by the barium in the hernial sac. Roentgenograms may also indicate the presence of a short esophagus of the congenital type when, in reality, the esophagus is not actually short but appears so because of the contraction of its longitudinal muscles, which elevates the cardia above the diaphragm due to an incompetent hiatus. The third point which I wish to emphasize is that an esophagoscopic examination is essential in all cases of hiatal hernia in which surgical treatment is being considered, because it is the most accurate method of determining whether there is any complicating lesion of the esophagus or cardia.

In considering cases of short esophagus from a surgical standpoint, it is important to differentiate them from true hiatal hernias because their surgical management is entirely different.

In cases of true hiatal hernia, the surgical problem is that of replacement of the herniated portion of the stomach into the abdomen, removal of the hernial sac, and repair of the muscle ring of the abnormally enlarged esophageal hiatus.

In cases of short esophagus of the congenital or acquired types, the surgical problem is that of elevation of the diaphragm and the crural fibers of the hiatal muscle ring to a position above the stomach, and the reconstruction of the hiatal muscle ring around the lower part of the esophagus at least 2 to 3 cm. above the cardia, because there may be some contraction of the longitudinal muscles of the esophagus after the operation.

Patients who have esophageal hiatal hernias of the short esophagus type often have associated stenosis of the esophagus for which dilatation should be performed before operation. These patients should be examined at frequent intervals after operation, because they may require more dilatations, depending on the subsequent course.

Great care should be used in the selection of these cases for surgical treatment, because of all the different types of esophageal hiatal hernia, the short esophagus type is the most likely to recur. Surgical treatment of elevation and reconstruction of the hiatal muscle ring should be considered in those cases in which a moderate shortening of the esophagus is present, and in this select group, conservative treatment should be tried before operation is done.

In some cases, interruption of the phrenic nerve and dilatation of the esophagus may relieve the symptoms. Patients who have severe symptoms that do not respond to conservative treatment and the usual operative reconstruction of the hiatus may require the more radical surgical treatment of transthoracic and transdiaphragmatic resection of the esophagus with esophagogastro-anastomosis.

DR. RICHARD H. SWEET, Boston, Mass.—Dr. Olsen made one statement which interested me a great deal. I have been puzzled by this and very much impressed by the clinical entity which he has pointed out. He mentioned that in one of his cases he thought the etiology was the presence of a carcinoma in the lower end of the esophagus, if I understood him correctly.

Of the 91 resections of carcinoma of the cardia, some of them arising in the stomach and some of them from the esophageal side—which I reported a while ago—exactly 13 per cent were present in a short esophagus and hiatus hernia syndrome. That seems to me to be a very high percentage, and I wish that he might comment upon it from the etiological standpoint.

DR. H. BRODIE STEPHENS, San Francisco, Calif.—The etiologic factors concerned with the production of the ulcerative and ultimate stricture in the group of patients presented by Dr. Olsen are particularly puzzling to me. It seems to me that there are certainly the same factors present in both varieties of hiatus hernias, yet the stricture is only present in the short esophagus type of hiatus hernia.

It is possible that the herniated portion of the stomach in the short esophagus type functions somewhat as a blind loop with the development of high acid concentrations in the portion of the stomach above the diaphragm. Such high acid values could account for the ulceration and stricture that is common to this type of hiatus hernia.

DR. CAMERON HAIGHT, Ann Arbor, Mich.—I would like to present for Dr. Alexander the case of a child of 4½ years of age whom he treated because of excessive bleeding from ulceration of the lower portion of a congenital short esophagus. We have had two such cases; in the second one it was possible to control the symptoms by antacid therapy combined with a temporary phrenic nerve interruption.

The first patient was admitted because of a profound anemia. The symptoms consisted of abdominal pain, occasional vomiting, and inability to take any food except milk. The hemoglobin on admission was 4.35 Gm. and the red blood cell count was 1.3 million. The vomitus at times was reddish brown in color and all stools showed a 4+ guaiac test. After many transfusions the hemoglobin increased to 11.8 Gm. but because of continued bleeding in spite of antacid and dietary management, further measures were required. To the best of our knowledge, esophagogastrostomy had not been employed previously for this type of lesion in a young child, and the case presented the particular problem of the advisability of esophagogastrostomy in a child of this age. As there appeared to be no alternative, Dr. Alexander proceeded in October, 1945, with resection of the lower esophagus and upper portion of the stomach followed by esophagogastrostomy.

(Slide.) The first roentgenogram shows the typical finding of a short esophagus which was presumed to be congenital because of the age of the patient. The second roentgenogram shows the appearance of the esophagus and stomach thirteen months after the esophagogastrostomy.

The child's condition was poor before operation. At operation the lower esophagus was found to be indurated and pathologic examination of the resected specimen showed the presence of a chronic ulcer. The postoperative convalescence was stormy and feedings were not tolerated well. A gastrointestinal roentgenogram showed the greater portion of the stomach to be within the left hemithorax, but there was no evidence of esophageal or pyloric obstruction. In view of the symptoms, a jejunostomy was performed one month after operation. His condition then very gradually improved and the jejunostomy tube was removed four and one-half months later. The patient was discharged from the hospital six months after the esophagogastrostomy.

Subsequent examinations on four occasions at intervals between nine and eighteen months after operation show that the patient is progressing unexpectedly well. He is eating all types of food, gaining weight and strength, and enjoying normal activities. There has been no recurrence of the bleeding. The postoperative roentgenogram thirteen months after operation shows essentially the same appearance of the stomach that was noted before the jejunostomy.

This case is mentioned because of the profound bleeding which resulted from the lesion, the use of esophagogastrostomy in the management of the problems and particularly the early age of the patient at the time of the operation.

DR. WM. E. ADAMS, Chicago, Ill.—We have had a number of these cases, most of them responding quite well to the treatment presented by Dr. Olsen, namely, repeated dilatation and medical measures. I wish to present some slides of a case that I saw about a year ago that presented a different problem.

(Slide.) This was a Mexican boy of 17, who had difficulty in swallowing shortly after birth. It was noted that he had some stricture. He was dilated repeatedly, but at the age of 5 a gastrostomy was necessary. Since that time he led a fairly normal life, developed normally, and when I first saw him, this x ray showed a complete obstruction at the lower part of the middle third of the esophagus.

Because of some experience with gastroesophagostomy for benign stenosis in other cases, I decided that it was the best procedure in his case.

(Slide.) Through an incision in the lower left chest, extending down in the abdomen, we brought the fundus of the stomach up after releasing and closing the gastrostomy and dividing the left gastric artery. It was relatively easy then to unite the esophagus above the point of obstruction with the fundus of the stomach by a side-to-side operation, very similar to a gastroenterostomy.

He tolerated the operation very well and, as you see here, the obstruction was completely relieved. Since that time he has gotten along very well.

(Slide.) The next slide shows the scar of the operation, extending down into the left upper quadrant of the abdomen. In patients where there is a high degree of obstruction, where dilatation has to be repeated frequently and gives less satisfactory results, I think an operation such as this type is useful.

DR. A. M. OLSEN, Rochester, Minn. Dr. Sweet has asked whether a carcinoma which occurs in conjunction with the short esophagus is the cause of the shortening of the esophagus, or whether the two conditions occur coincidentally. This question is very difficult to answer. Carcinoma of the cardiac end of the stomach often involves the outer walls of the esophagus. It is our impression that invasion of the lower part of the esophagus by a gastric carcinoma may result in shortening of the esophagus. There is no reason, however, why carcinoma cannot arise in the shortened esophagus or the intrathoracic portion of the stomach.

Dr. Stephens' question concerns the development of stenosis of the lower part of the esophagus in patients who have esophageal hiatal hernia. The cardiac sphincter often is incompetent in the presence of hiatal hernia. Gastric secretions regurgitate into the lower part of the esophagus and may cause severe esophagitis. As this esophagitis heals, contraction and stenosis of the lower portion of the esophagus is likely to occur.

I am very glad that Dr. Adams could discuss his experience with esophagogastrostomy for strictures associated with esophageal hernia in the presence of a short esophagus. Reference to the work of Clark and Adams is made in the text of this paper. Although we feel that most of these strictures can be treated successfully by means of dilatation, there are certain cases in which a surgical procedure, such as that described by Dr. Adams, would be most valuable. I was interested particularly in the patient with esophageal stricture associated with scleroderma who was treated by esophagogastrostomy.

RESECTION OF A COARCTATION OF THE AORTA WITH SUBCLAVIAN-AORTIC ANASTOMOSIS

Report of a Case With a Discussion of a New Clamp for Aortic Resection and Anastomosis

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Felda Hightower, M.D. (by invitation)
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THE signs and symptoms of coarctation of the aorta form a well-known symptom complex that needs no repetition now. The diagnosis is not difficult if the possible existence of the lesion is considered.

The prognosis in patients afflicted with this deformity is rather poor unless the patients are treated surgically, and approximately 75 per cent of them will die before the age of 40 years. Hines and Christensen[1] have listed three types of events which may lead to death. First, the condition may remain latent throughout life and death may occur suddenly from a ruptured blood vessel or from conditions unrelated to the vascular anomaly. Second, cardiac insufficiency may occur rather suddenly in an apparently healthy individual and progress to complete decompensation and death. Third, chronic cardiac insufficiency may lead to cardiac failure and death. Subacute bacterial endocarditis and aortitis may also occur.

In view of the poor prognosis in untreated patients, and the encouraging results which have been secured by Crafoord and Nylin,[2] Gross,[3] and Clagett,[4] it is reasonable to advise patients with this deformity to have surgical correction.

Apparently, the first attempts to apply experimentally obtained experience in the surgical correction of coarctation of the aorta was made by Crafoord and Nylin[2] in October, 1944. At that time, two patients were successfully operated upon. Since then Gross[5] has operated upon at least sixteen patients with two deaths; Crafoord[2] has completed two such operations, and Clagett[4] has performed one at last available report. In some of these patients where the coarcted area is rather long, difficulty may be experienced in anastomosing the ends of the aorta after resection of the narrowed portion. It may not be possible to bring the aortic ends together at all, or, if they are approximated, the tension required to maintain them may cause the sutures to break or tear through the aortic wall, especially if it is atheromatous. In such a situation, the procedure used experimentally by Blalock and Park[6] may prove valuable, that is, anastomosis of the proximal end of the divided left subclavian artery to the distal end of the aorta after resecting the coarctation. This method was used by Blalock and Park[6] on a series of forty-three dogs. In each the aorta was severed at the level of the obliterated ductus and both ends were sutured. The left subclavian artery was then divided and its proximal end sutured to the aorta

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by an end-to-side anastomosis. Ten of these animals survived for several months or longer. The predominating complication was paralysis of the posterior part of the body.

These results, although not too encouraging, do not mean that this procedure is contraindicated in patients who have coarctation, and where the aortic ends cannot be approximated after the coarctation is resected. This is true for two reasons. First, patients with coarctation may well have a left subclavian artery which is dilated to the same caliber as the aorta below the coarctation, and it could thus shunt a great deal more blood to the distal aorta than could an undilated left subclavian artery in an otherwise normal dog. Second, even if the left subclavian artery were somewhat smaller in diameter than the aorta distal to a coarctation, it would still be larger than the area of the coarctation itself, and the other collateral channels already present could play an important part in transporting blood to the lower two-thirds of the body.

Resection of aortic coarctation with subclavian aortic anastomosis has been performed on two human beings. Clagett,[4] in August, 1946, carried out this procedure on a 34-year-old man and the patient survived. A similar operation was done on the patient herein reported, but death ensued twenty-four hours after operation from pulmonary edema and atelectasis. In neither patient was there any suggestion after operation of any paralysis in the legs or left arm.

The patient operated upon by Dr. Bradshaw was a 16-year-old white man admitted to the North Carolina Baptist Hospital on Dec. 16, 1946. Three months prior to admission he had noted the onset of dizzy spells when he would rise to his feet from a sitting or lying position. At the same time he noted the onset of frontal headaches, pain in his anterior chest to the left of his sternum, dyspnea on exertion, and some pain and tenderness in the anterior muscles of his thighs. He had also complained for a long time of cold feet. He had consulted three physicians at various times and was told he had high blood pressure. The fourth physician, after an examination which included a chest x-ray, told him that he had a disorder of a large blood vessel in his chest.

When a younger boy he had had frequent nose bleeds and sore throat. An appendectomy had been done in 1944, and several months prior to admission he had been treated in another hospital because of impairment of renal function. At that time, his blood nonprotein nitrogen was reported to have reached a high of 260 mg. per cent. When examined at the time he came to the hospital, there was slight fullness of the veins of his neck. Systolic blood pressure readings in the right arm averaged 142 mm. of mercury, and in the left arm between 136 and 152 mm. of mercury. Diastolic blood pressure in the right arm averaged 70 mm. of mercury, and in the left arm varied between 64 and 70 mm. of mercury. In the legs, the systolic blood pressure readings varied between 84 and 108 mm. of mercury, while the diastolic readings varied between 60 and 80 mm. of mercury.

There was a loud systolic murmur in the pulmonic area as well as a blowing diastolic murmur in the same zone. Several pulsating intercostal vessels could be palpated over the posterior chest wall.

The radial pulses were full and forceful, while the pulsations of the abdominal aorta, femoral, posterior tibial, and dorsalis pedis arteries were markedly diminished.

Fluoroscopic examination and x-ray films of the chest showed an aortic knob, slightly smaller than usual, with no mediastinal enlargement. The descending portion of the aorta could not be well visualized. Motion of the heart and diaphragm were normal. The lung fields were clear and notching of the inferior rib margins was noted.

The electrocardiogram gave no evidence of myocardial disease. The blood counts and urinalyses showed no abnormalities. The blood nonprotein nitrogen and total serum proteins were normal and the phenolsulfonthalein test of kidney function showed 80 per cent excretion in ninety minutes.

This patient was operated upon on Dec. 21, 1946. A left posterolateral approach was employed and a segment of the fourth rib was removed. The intercostal arteries and veins were markedly dilated and at the insertion of the ligamentum arteriosum into the aortic wall a definite aortic constriction was present, below which no aortic pulsations were palpable (Fig. 1, *A*). The process of freeing-up the aorta was troublesome because of venous bleeding from a rich plexus of dilated vessels. The ligamentum arteriosum was divided and a 3 cm. segment of aorta containing the coarctation was excised between clamps (Fig. 1, *B*). The lumen at the coarcted level was but 4.5 mm. in diameter and a soft organizing thrombus was present at this point.

When an attempt was made to suture the aortic ends together, it was felt that the tension on the sutures was excessive and that it would be difficult and hazardous to try to complete the anastomosis. The only alternative was to utilize the left subclavian artery which was dilated to the same diameter as the aorta. Accordingly, the proximal aortic stump was closed and the left subclavian was freed up and divided between clamps at a point 4 cm. from the aortic arch (Fig. 1-*C*). The distal subclavian stump was sutured and the proximal subclavian stump was rotated caudad, Fig. 1-*D* and was anastomosed to the distal aortic stump using an everting suture of 3-0 Deknatel silk. (Fig. 1, *E* and *F*.)

Total operating time was five hours. Postoperatively, the patient's condition remained critical. Pulses in the legs were felt on only one occasion about eighteen hours after operation. Blood pressure in the legs could not be recorded. The radial pulse rate averaged 130 per minute and blood pressure readings in the arms remained high, averaging 200 mm. of mercury systolic and 80 mm. of mercury diastolic.

The patient died twenty-six hours after completion of the operation. At autopsy, he was found to have edema of the right lung and atelectasis of the left lung. The anastomotic site was partly obstructed by a thrombus. The degree of coronary artery sclerosis which was present in this young patient was quite remarkable.

Long intestinal clamps were used to occlude the vessel ends while this anastomosis was being completed, and it was quite difficult to keep the cut ends of the vessels absolutely immobile in accurate end-to-end approximation. The result was that the fine sutures being used broke with annoying frequency. An attempt was made, therefore, to design a clamp which would firmly grasp the aortic wall between parallel bars without crushing, and which would permit the vessel ends to be accurately approximated to each other and immobilized.

Such clamps were designed and the original model was made through the kindness of Dr. J. Earle Thomas and Mr. William Goebbels, Professor of Physiology and Instrument Maker, respectively, at the Jefferson Medical College in Philadelphia.* This instrument is shown in Figs. 2 and 3.

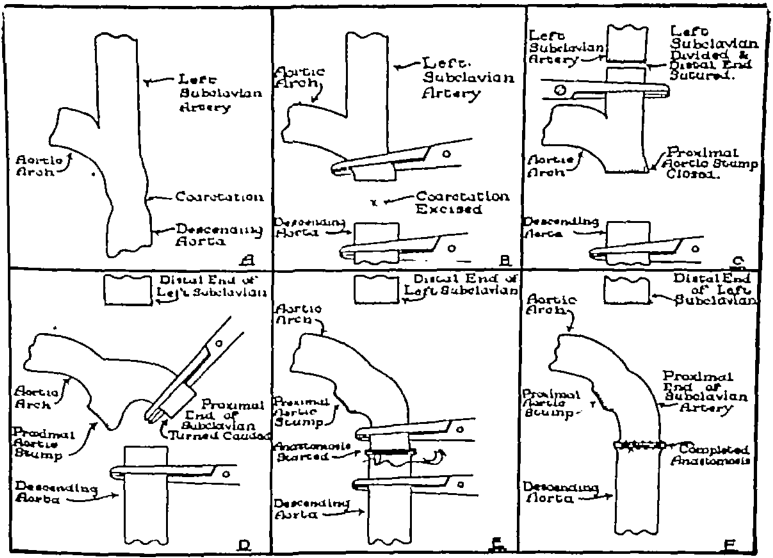

Fig. 1.—Diagrammatic representation of operative steps followed in the patient reported.

It consists of four parts: two clamps having parallel jaws 5 cm. long, the pressure on the jaws being accurately adjustable by means of a knurled nut; an octagonal rod 8 cm. long having a ball on either end, and threads on its four "corner" surfaces to receive a knurled nut. This rod can be inserted into square holes in each clamp so that it holds them in constant alignment with each other and permits them to be moved to or from each other. A handle, 18 cm. long can be attached by a ball-and-socket joint to either end of the bar. The handle can be moved through a wide range with respect to the bar and locked in any position desired.

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*These clamps are now being supplied by the George P. Pilling & Sons Company, 3451 Walnut Street, Philadelphia, Pa.

This instrument has been employed experimentally on fifteen occasions and has proved satisfactory. When in use, the clamps can be removed from the bar or left on it and placed transversely across the aorta one above and one below the segment to be resected. The jaws can be closed to any desired pressure by turning the knurled nut, and the aorta can be thus occluded. It is important when applying these clamps to place the aorta in each clamp equidistant from the tips of the clamp so that when the clamps are joined by the bar and approximated, the aortic ends will be in accurate end-to-end apposition.

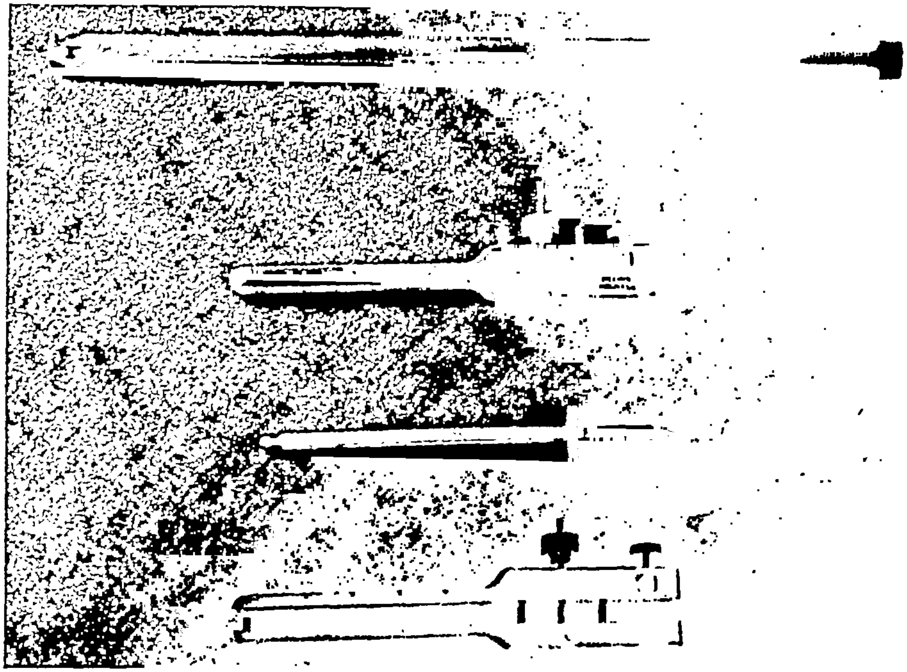

Fig. 2.—Photograph of the clamp disassembled to show its parts.

The desired segment of aorta can then be excised, leaving a free cuff about 8 to 10 mm. long on each side between the cut ends of the aorta and the clamps. (Fig. 4-*A*.)

If the clamps are removed from the bar before application, they can be joined by the bar after the aortic segment has been excised. The left hand clamp is locked on the bar by means of the small set screw, while the right hand clamp is left unlocked on the bar. Using the knurled nut on the bar, the right hand clamp can be moved toward its fellow (if desired, this relationship can be reversed) thus approximating the aortic ends. Both set screws are then tightened and the ends of the vessel are accurately secured in a satisfactory position for exact suturing. (Fig. 4, *B*.)

A running horizontal mattress suture of 4-0 braided silk has been used in the experiments done to date. This everts the aortic ends and allows for intima-to-intima healing. This suture is started on the upper surface of the aorta at a point near the edge of the vessel which is farther from the operator. It is carried around the far edge of the aorta (Fig. 4, *B*). The clamp can then be rotated away from the operator (Fig. 4, *C*) and the suture line continued on the under surface of the aorta. When the nearer edge is reached, the clamp can be rotated again toward the operator and the suturing completed on the upper surface. (Fig. 4, *D*.)

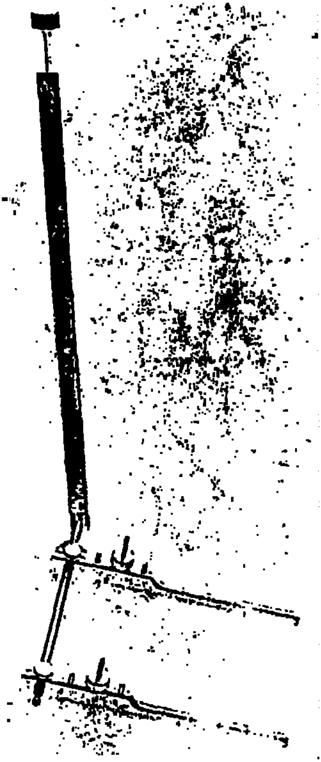

Fig. 3.—Photograph of the assembled clamp.

The distal clamp can then be slowly released but left loosely astride the aorta should it be needed again. The proximal clamp can then be released very slowly over a period of several minutes and also left loosely across the aorta.

Should leaks occur, they can usually be controlled by steady pressure with a gauze sponge. If this is not sufficient, both clamps can be again tightened and an extra suture inserted.

The running horizontal mattress type of stitch is favored because it everts the edges nicely and causes much less strangulation of tissue than closely placed interrupted horizontal mattress sutures.

To date this clamp has been used experimentally on fifteen dogs. In each animal the aorta was approached through the left chest and segments of aorta varying in length from 4 to 12 mm. were excised.

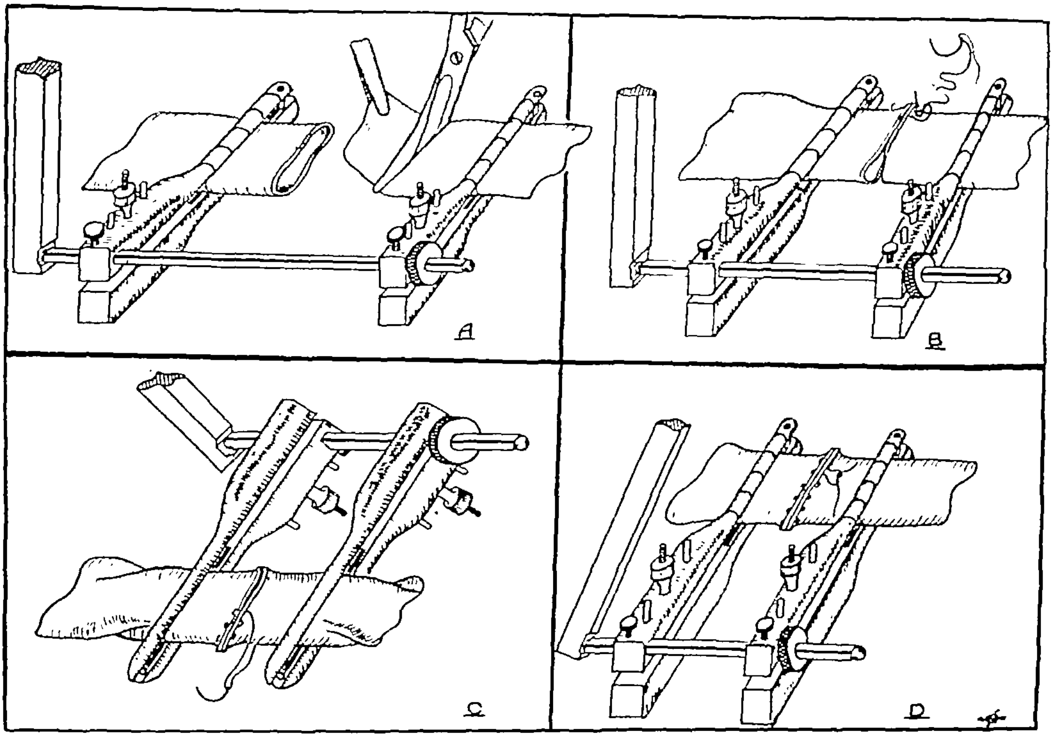

Fig. 4.—Diagrams of technical steps followed in the experimental resection and suture of the aorta. *A*. The clamps mounted on the horizontal bar have occluded the aorta and a segment is excised from between them. Note cuffs of aorta allowed to remain. *B*. The clamps have been moved together on the horizontal bar so that the aortic ends are apposed. A continuous horizontal mattress suture has been started on the "upper" surface and is being run around the edge farther from the operator. *C*. The clamp and aorta have been rotated away from the operator and the suture line is continued on the under surface. *D*. The clamp and aorta have been rotated back toward the operator and the suturing completed.

In the first ten dogs operated upon, sodium pentobarbital anesthesia was used in dosage of 30 to 40 mg. per kilogram of body weight. In each animal, pulmonary ventilation was carried out under positive pressure with atmospheric air administered by means of endotracheal tube and a motor-driven interrupter. In this group there was one survival and nine deaths. Three dogs died at the time of operation, one from anesthesia, and two from hemorrhage as a result of constant tearing of the aortic wall. Both dogs having friable aortic walls were older animals, and in addition to the sutures tearing through the coats, the layers of the aortic walls separated readily from each other. This raises the question as to the ability of an older aorta to retain sutures. Many observations on many human patients will have to be made before such a question can be answered, but it is of importance with relation to the optimum time for resecting an aortic coarctation. Speaking from the purely technical standpoint of suturing, it may be preferable to resect aortic coarctation early in the life of the patient before the aortic wall proximal to the coarctation has become physiologically old.

In this same group of ten dogs, two died within twenty-four hours with paralysis of the hind legs, bowel, and bladder; two died at four and six days after operation, respectively, from hemorrhage; one died on the fifth day of infection; and one died on the sixth day with paralysis of the rear legs, bowel, and bladder.

Thus four out of seven dogs surviving the operation, per se, had paralysis of the rear legs, bowel, and bladder. These dogs had large bowel evacuations while the aortic clamp was in place as well as after its removal.

It is felt by many investigators in this type of work that these paralyses are the result of ischemia of the spinal cord. The length of time during which the aorta can be clamped without developing a paralysis of hind legs in a dog has been variously estimated by many observers, but is usually considered to be about fifteen minutes. There is, however, an apparent variation in this period of occlusion, for in dogs with aortas occluded thirty to forty-eight minutes, paralysis has not occurred.

Various measures have been used in attempts to overcome this complication. Gross and Hufnagel,[7] in their experimental work, cooled the lower part of their animals in order to lessen the severity of this complication. We have considered the use of some by-passing operation similar to those used by Carrel[8] in 1910, and also the use of transfusions into the distal aorta while the aortic clamps are on. How extensively this type of procedure should be investigated is a matter of conjecture, because conditions in these dogs are far different from those in human patients with coarctation where an extensive collateral circulation already exists. However, we did feel it worth while to investigate the possibility of the use of high concentrations of oxygen to see whether it would have a beneficial effect in reducing these neurologic complications. Accordingly, in the next five dogs operated upon, the same anesthesia and the same technique was used, but, in addition, oxygen at the rate of 4 L. per minute mixed with room air was administered through the positive pressure respiratory apparatus. It was felt if the oxygen saturation of the blood could be raised to its maximum point before the aortic clamps were applied, then while the clamps were in place and the aortic circulation completely obstructed, the tissues distal to this site would have a somewhat larger reserve of oxygen to help to tide them over the period of occlusion.

Three dogs breathing room air after administration of sodium pentobarbital anesthesia were found to have an average oxygen saturation in their venous blood of 74.4 per cent. After the aortas had been occluded for 20, 25 and 25 minutes, respectively, the average oxygen saturation in femoral vein blood was 11.6 per cent, while oxygen saturations in venous blood from the forelegs averaged 80.1 per cent. The hemoglobin values in these dogs varied from 8.7 to 12.1 Gm. per cent.

Two other dogs breathing room air after administration of sodium pentobarbital anesthesia had average oxygen saturations in their venous blood of 82.1 per cent. These two dogs were then given oxygen at a rate of four liters per minute mixed with room air via an endotracheal tube and the oxygen saturation of venous blood rose to an average of 98.4 per cent. Oxygen plus room air was continued while the aorta was occluded. After periods of aortic occlusion of twenty-three and twenty-eight minutes, respectively, the oxygen saturation of femoral vein blood averaged 16.6 per cent, while the oxygen saturation of venous blood from the foreleg averaged 101.0 per cent. The respective hemoglobin levels in these dogs were 12.6 and 13.5 gm. per cent.

Thus, by administering high concentrations of oxygen to these animals, the oxygen saturation of femoral vein blood after twenty-five to thirty minutes of aortic occlusion was increased from 11.6 per cent to 16.6 per cent. Further, none of the dogs receiving oxygen had any paralysis of their hind quarters, and the occurrence of profuse bowel evacuations was greatly reduced. Of five dogs receiving supplementary oxygen, two died eight and eleven days, after operation respectively, as a result of hemorrhage from the site of anastomosis. The other three are living and well 56, 75, and 76 days postoperatively.

There are certain details of this clamp which can be improved upon, but so far in its experimental use the basic principles of its design have proved useful. As further experience accumulates experimentally and clinically, it will doubtless be modified and it may be advantageous to make a somewhat similar instrument in different sizes for use in patients of varying sizes.

We are deeply grateful to Dr. James W. Dickey, Jr., and Dr. Louis Shaffner for their very generous assistance in operating upon these dogs and carrying out the determinations of blood oxygen.

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DISCUSSION

DR. HOWARD BRADSHAW, Winston-Salem, N. C.—We tried the clamps Dr. Gross had suggested, and we found a great deal of difficulty in holding the aortic ends together. With each pulsation, of course, they gave a bit, and sutures pulled out, particularly if, as you have noticed in the movie, the lower end of the aorta is diseased. Stitches pull out easily in such a blood vessel.

We have used the clamp in dogs, and it works well with them. We have not had occasion yet to use it in patients.

Any of you who are interested in this clamp can see it some time during the meeting. It was made by the Department of Physiology, Jefferson Medical College, Pa. I am sure there are many wrinkles that can be improved upon, and we would appreciate suggestions.

We wanted to get a clamp that would not slip and would not be in our way too much. It is a very simple idea, and we do not deserve any credit for originality. We put that handle on so that it is possible to use it at most any angle desired.

This does hold the severed ends in approximation without any doubt. The clamps can be adjusted tightly or loosely, and so far it has seemed in normal aortas, at least, in dogs, that it is quite an adequate instrument for an end-to-end anastomosis of the aorta.

In the movie you noticed there was not much left of the upper stump of the aorta, and I think it is wise to have a better clamp than just an ordinary stomach or intestinal clamp with someone holding it. One can rotate this clamp either way, and put the posterior sutures first.

There is no doubt about being able to secure an accurate approximation of the aortic ends. We have operated upon some fifteen dogs with it, and the anastomosis has been uniformly satisfactory. We have found that—with our very limited experience—the time that one can clamp off the aorta is very variable, and we think that an oxygen-rich atmosphere helps a great deal in preventing hind leg paralyses.

DR. STUART W. HARRINGTON, Rochester, Minn.—At the present time this procedure is essentially an operation of necessity rather than one of choice. For that reason, I believe it is important to evaluate it as to whether it is a justifiable palliative operation to substitute for resection of the stenosed area and end-to-end anastomosis.

Dr. Clagett has done several of these operations, and I am sorry that he is not here to report his experience with this procedure. He has given me a summary of the cases he has done, to present to you, which I will read.

"Our experience with the anastomosis of the subclavian artery to the thoracic aorta in the treatment of coarctation consists of five cases at the present time. In each case the patient was explored with the hope that it would be possible to do the classical type of operation with excision of the stenosed area and an end-to-end anastomosis. In these cases, either because of the location or the extent of the stricture, it was not feasible to carry out this technique, and in each the subclavian artery was used. In four cases the stenosed area was ligated, the aorta was sectioned just distal to the stricture, the subclavian artery was sectioned, the distal end ligated, the proximal end rotated over, and an end-to-end anastomosis to the thoracic aorta achieved. In the fifth case the stenosis of the aorta was not complete. There was a thrill indicating some blood going through the strictured area. In that case the end of the subclavian artery was anastomosed to the side of the thoracic aorta. The patients were 34, 31, 28, 21, and 18 years of age. All had rather severe hypertension in the upper body, with blood pressures ranging from 185 to 230, and in all the blood pressures in the lower extremities were low or unobtainable. The most predominant symptoms were headache, dizziness, and weakness. Two patients complained of severe weakness in the legs after moderate exercise. Three of the patients had been referred to the clinic for sympathectomy because of a diagnosis of hypertension; in the other two a diagnosis of coarctation had been made elsewhere previously.

"The postoperative course of three of the patients was uneventful, and they were dismissed from the hospital in good condition. The fourth patient had a little persistent fever and died on the thirty-second postoperative day from hemorrhage due to separation of the posterior wall of the anastomosis. The last patient is still in the hospital. Her postoperative course has been satisfactory. All the patients but one obtained a satisfactory decrease in their arm blood pressures postoperatively, and simultaneous increased femoral blood pressures. The patient who did not obtain such a satisfactory result is the one in whom the end-to-side rather than the end-to-end anastomosis was performed. The first patient we operated on had a blood pressure of 230/140 before operation, and when seen recently, six months later, his arm pressure was 152/80 and his leg pressure, 154/86.

"This group of patients is older than is desirable for surgery, since in every case there was a rather severe degree of sclerosis of the vessels. It certainly would be preferable to operate on younger individuals; however, we have not felt that these patients should be denied operation. There has been no difficulty with the left arm resulting from ligation of the subclavian artery. The arm is a little cooler and radial pulsations cannot be felt, sometimes, for days or even weeks after operation, but there has been no weakness or disability and collateral circulation appears to be entirely adequate.

"There are obvious disadvantages to the use of the subclavian artery for the anastomosis rather than making an end-to-end anastomosis of the aorta after resection of the stricture. The use of the subclavian for anastomosis to the aorta does not increase the vascular bed through which blood is evacuated from the heart, but the resistance is materially decreased and allows a more normal adjustment in blood pressure in the upper and lower portions of the body. The advantages in the use of the subclavian are that an anastomosis can be performed without tension on the anastomosis, and that it is possible to perform the operation in a patient in whom the stricture is too long to permit an end-to-end anastomosis.

"It is much too early to evaluate the end results of these patients. They all have had a rather severe degree of arteriosclerosis, and we cannot anticipate these blood vessels will return to a normal condition. However, the decrease in blood pressure to the upper body and the improvement in the blood supply to the lower body should give the patient a great deal of protection against cardiac failure and cerebral accidents. From our experience so far, we are encouraged and believe the procedure has a very useful place in the treatment of those patients in whom it is impossible to establish an end-to-end anastomosis of the aorta."

DR. JULIAN JOHNSON, Philadelphia, Pa.—I would like to show some slides on a couple of these patients that we have had occasion to operate upon in the last few months.

(Slide.) These patients both had the so-called infantile type of coarctation, in that the coarctation extended over a long area. By actual measurement, the area that had to be resected here was in the neighborhood of 4 or 5 cm. Obviously, it would be impossible in this patient to do an end-to-end anastomosis.

In this slide the head is upward, the descending aorta down below. The vessel going upward is the large subclavian artery. We were not aware that anyone had used the subclavian before, but it was such a logical procedure that we went ahead with it.

(Slide.) This was a 13-year-old boy. As you bring it down, you see the difference in the size of the subclavian and the descending aorta, and this boy, where he had a previous blood pressure in the neighborhood of 170 over 110 to 120, has dropped down now to a blood pressure of 100 over 70, and has good, bounding pulses in his leg.

(Slide.) That boy has had an excellent result as far as we can see. Now, three months later, he has as good a result as he could have gotten by any means.

(Slide.) On the other hand, here is an 18-year-old boy. The first one had a complete obliteration of his aorta. This was not complete. Here you cannot see the subclavian up above, but we thought that the subclavian artery was larger than the little stump of descending aorta, and so elected to do the same procedure.

(Slide.) Again, we had to resect about 4 cm. of the aorta. As you see, in this patient we thought that there was a greater difference in the size between the subclavian and the descending aorta. This boy had an excellent bounding pulse in his feet, immediately after operation. The next day, however, it had diminished considerably, although we could still feel it. We thought that perhaps he must have had some thrombosis going on at the site. It gradually came around again, and within a period of a month after operation had improved considerably. His blood pressure, however, has not dropped to normal. It was in the neighborhood of 200 before operation. It has come down to 170, and not returned to normal. We presume that whereas there was some flow through the aorta at the time, we are not sure we increased his blood flow, and have not increased it sufficiently to return him to a normal blood pressure.

DR. JOSEPH W. GALE, Madison, Wis.—The first case which we did about three months ago turned out beautifully. We did a good end-to-end anastomosis. The coarctation was about a centimeter below the base of the subclavian. We placed a homemade clamp above it which worked very well.

The individual had systolic pressure of 200 to 220 over 100 and 110 previous to the operation. Immediately after the operation it fell to normal and has remained there.

In the second case, the coarctation was so close to the subclavian that we could not place a clamp above it, so that necessitated utilizing the left subclavian. There was quite a difference in the size of the distal aorta and the subclavian, so we had to cut the latter on a bias. We performed a fair anastomosis. This 18-year-old patient had a blood pressure of 170 over 100, following the operation it fell to 120 over 70. This pressure was maintained for three and one-half days. Since then it has risen, until now, fifteen days after operation, it varies between 180 and 210.

I think there is something wrong. I don't know what it is, but suspect that there is a thrombosis at the site of the anastomosis.

I would like to ask some of you gentlemen who have had more experience what the chance of thrombosis is in these cases.

We did a number of these operations on dogs, previously, and it probably took us too long to perform the operation, since they all developed paralysis of the lower extremities, and every one developed a thrombosis. Now if a thrombosis has occurred in our second patient, have we done him any harm, or will there be some recanalization and improvement later? Right now we are rather discouraged about the outcome of this case.

DR. HOWARD T. BARKLEY, Houston, Texas.—I just wish to add one case, interesting from the standpoint of pathology.

This was a patient 40 years of age, completely incapacitated by the most severe cerebral hypertension. At operation we found a greatly thickened aortic wall, and at the site of the resection of the coarctated area, a thickened atheromatous plaque was encountered on the medial wall of the proximal cut end of the aorta; therefore, we had to resect a triangular segment out of the aortic wall, just distal to the subclavian artery, to remove this plaque. Anastomosis was accomplished.

This patient died forty-eight hours postoperatively, with sudden pain and shock. We supposed that our anastomosis had given away and he had bled, but on post-mortem examination the anastomosis was intact. It was found that the Crafoord clamps had been placed across other atheromatous plaques above and below the point of anastomosis and had fractured the intima over these plaques. A mural thrombus had formed, which was attached at the site of the fractured intima above and below the anastomosis but was not attached to the suture line. The lumen of the aorta was not occluded, and we were unable to determine the cause of death. There was no coronary thrombosis.

DR. H. BRODIE STEPHENS, San Francisco, Calif.—We have employed retrograde injections of 35 per cent Diodrast solution to demonstrate coarctation of the aorta. We have injected 25 c.c. of the 35 per cent solution into the left common carotid artery of several children around 4 years of age where the diagnosis of coarctation was questionable by clinical examination. The left common carotid artery is exposed in the neck and a No. 18 gauge needle inserted retrograde into this blood vessel. The diodrast solution is injected as rapidly as possible while roentgen films (left lateral oblique) of the chest are taken in rapid succession during the injection of the diodrast solution. This procedure is carried out under general anesthesia. An excellent demonstration of the aortic neck, the thoracic aorta and the abdominal aorta is obtained by this technique. We have not obtained any ill effects from retrograde injections carried out in the manner just described.

DR. LOUIS R. DAVIDSON, New York, N. Y.—In discussing this interesting presentation of Dr. Bradshaw I should like to make two observations which are based upon the experiences gathered by Dr. Jere Lord and myself. At Post-Graduate Hospital in New York City we have operated upon different types of congenital hearts; at Cornell Medical College we have performed our animal work. In consequence of our experiences we have come to the conclusion, as most of you have, that these strictures of the aorta must be considered from two viewpoints—extent and location.

It is obvious that a long stenosis of the aorta precludes operation of the orthodox type since the ends of the aorta cannot be approximated and sutured. At times, even in the so-called average case, it is difficult to have the sutures hold in the vascular wall. The location of the coarctation also creates problems. In one of our cases, lantern slides of which will be shown in a moment, we were quite apprehensive throughout the entire operation by virtue of the fact that we had but 3 mm. of aortic cuff projecting from the proximal clamp. This clamp just avoided the left subclavian artery. Because of this experience we have performed the following operation which we hope will obviate this difficulty, thereby making the procedure less hazardous. I may say parenthetically that this operation has been performed only in the animal laboratory and as yet not upon a human.

The aorta and the left subclavian artery along with the intercostal arteries are mobilized in the customary fashion. This holds true for the ligamentum arteriosum. At the start, like most others, we were very cautious in our approach to the left vagus and the left recurrent laryngeal nerves. We have lost our fearfulness and have found that there is no apparent disturbance following careful liberal mobilization of these neural structures. When the vessels and the nerves have been adequately prepared and particularly the aorta freed posteriorly a Blakemore-Crump clamp is placed upon the aorta between the left carotid and the left subclavian arteries. Over the distal aorta a Bainbridge clamp is placed and on the left subclavian artery a bulldog clamp is applied. This permits sectioning of the aorta flush with the take-off of the left subclavian artery, removing the coarctation distal to the section. Then, without rotating the vascular structures, an anastomosis between the distal aorta and the aortic arch is made. We propose this operation for those cases of coarctation of the aorta where the problem of applying the proximal clamp arises in consequence of the high stenosis. Dr. Lord and I believe this procedure has certain merits:

A. High strictures can be readily handled without sacrificing a vessel.
B. Rotation of the aorta is unnecessary.
C. Alarming hemorrhages can be avoided.

Just one other matter: Dr. Maier, I believe, in his presentation, by indirection implied that all cases should have an angiocardiogram. We subscribe to that statement quite definitely.

(Slide.) This angiocardiogram was made for us postoperatively by Dr. Henry K. Taylor. You note that the proximal aorta is fully visualized.

(Slide.) Here one sees the distal aorta well outlined.

(Slide.) In this third slide we obtained information which, if known earlier, would probably have precluded surgery. The left subclavian artery is not visualized and probably is absent. The right subclavian artery arises from the left side of the arch of the aorta. One notes a marked collateral circulation with a very markedly enlarged right internal mammary artery. In this case the coarctation was just distal to the left common carotid artery. Here, in desperation, because of the location of the constriction, the end of the left third intercostal artery was anastomosed to the side of the carotid artery. This patient, 10 years of age, obviously has failed to show any improvement. Fortunately his condition has not been made worse.

DR. JAMES F. O'NEILL, Winston-Salem, N. C.—Because we stopped the movie before it had fully run through, I don't think that we could appreciate the severity of the coarctation he had. Looking at it from the outside of the aorta, it did not seem to be very great, but after a specimen was excised, the internal lumen of this coarctated area was only about 3 mm.

Second, at autopsy this patient showed marked coronary sclerosis, and a great deal of sclerosis in the aorta proximal to the coarctation. This may be a physiological aging process, but we are not certain of that.

AORTIC-PULMONARY ANASTOMOSIS FOR PULMONARY STENOSIS

WILLIS J. POTTS, M.D. (BY INVITATION)
CHICAGO, ILL.

CYANOSIS due to certain types of congenital heart disease can now be relieved surgically in a fair percentage of cases. It must be demonstrated that the patient has an insufficient flow of blood to the lungs as manifested by cyanosis, increased red blood cell count, increased hemoglobin, decreased oxygen saturation of arterial blood and a markedly decreased tolerance for exercise for the condition to be suitable for surgery. In patients with typical pulmonary stenosis as part of the syndrome of the tetralogy of Fallot, x-ray and fluoroscopic examination should reveal: a fairly typical boot-shaped heart with a concavity in the region of the pulmonary conus on the left, a "pulmonary window" in the right anterior oblique and left anterior oblique views, and absence of pulsations in the hilar regions of the lungs. A barium swallow will usually reveal whether *the aortic arch curves to the left or to the right. A concavity in the barium on* the left side of the esophagus indicates a left aortic arch and a concavity on the right side indicates a right aortic arch. The electrocardiograph in these patients must show a deviation of the axis to the right. In children with tricuspid atresia the heart is likely to be rather globular and slightly flattened on the right in the region of the right ventricle. The electrocardiograph in such patients shows a deviation of the axis to the left. A cyanotic child with a large heart or a prominent pulmonary conus, with increased hilar markings or visible pulsations in the lung fields on fluoroscopic examination does not fall in the operable group.

Operative success will depend upon an accurate diagnosis of the type of congenital heart disease and a careful selection from this group of those who may be benefited by surgery. The diagnostic work at the Children's Memorial Hospital is done by Dr. Stanley Gibson. Because of publicity it is quite natural for each mother of a cyanotic child to anticipate that her unfortunate youngster can be successfully operated upon. This is far from the truth. In our experience approximately one-half of the children with varying degrees of cyanosis due to cardiac abnormalities have conditions which are unsuitable for operation. Even so, we have operated upon a number of children in whom the diagnosis was questionable but whose condition was such that exploration was indicated since surgery offered the only chance for survival.

Following the outstanding work of Blalock and Taussig[1] in this field of surgery, interest in these hitherto hopeless cyanotic children has revived. In a large series of patients they have been successful in transforming anoxic children from helpless to happy and fairly normal individuals. To increase the flow of blood to the lungs, Blalock anastomoses one of the large systemic vessels

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From the Children's Memorial Hospital and from the department of experimental surgery, Northwestern University Medical School, Chicago, Ill.

Read at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29 and 30, 1947.

to a pulmonary artery. Use of the subclavian has resulted in no permanent damage to the arm but use of the innominate or carotid arteries has led, in a certain percentage of cases, to transient or permanent damage to the brain. Because of this danger, it occurred to me that it might be possible to establish a ductus arteriosus between the aorta and a pulmonary artery if by some means a fair portion of the blood could be allowed to flow through the aorta while the anastomosis was being made. In November, 1946, a new procedure for the relief of cyanosis due to pulmonary stenosis was published with Drs. Smith and Gibson.[2] The principle worked out in the experimental laboratories at Northwestern University Medical School involved in the use of a clamp which encircles the aorta and pinches off a small lip of it to which a pulmonary artery can be anastomosed. At the same time the clamp allows plenty of blood to continue to flow through the partially constricted aorta (Fig. 1). Although the technique has remained substantially the same as previously described, a few details and their significance are worthy of note.

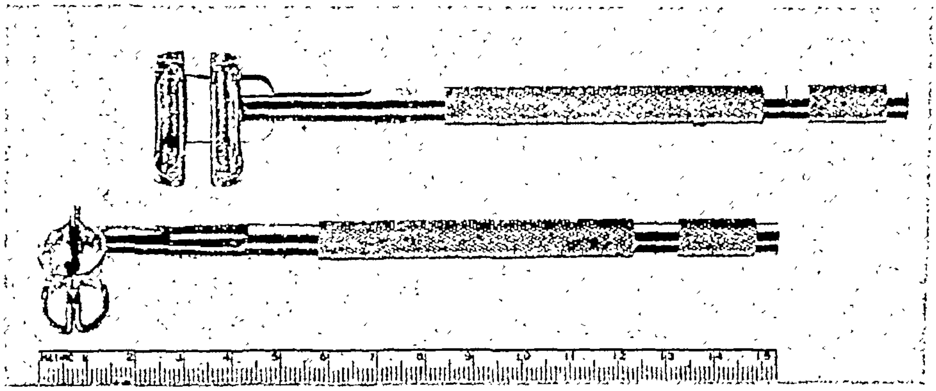


Fig. 1.—Aortic clamp.

I cannot emphasize too strongly the importance of expert anesthesia. All patients operated upon in this series were anesthetized by Dr. William O. McQuiston. Cyclopropane has been the anesthetic agent of choice because of the high concentration of oxygen that can be given with it. Ordinarily these patients become less cyanotic as soon as the anesthesia is begun. The actual technique of anastomosis will be tremendously aided by the anesthetist who is able to stop reflex respirations and "breathe for the patient" by rapid intermittent pressure on the anesthetic bag. This maneuver stops all movements of the diaphragm and allows the aorta and pulmonary artery to lie absolutely motionless. Curare in small amounts has been of great assistance in controlling respiration.

It will be noted from the illustration (Fig. 2, *E*) that the posterior row of sutures apposes the aorta to the pulmonary artery, adventitia to adventitia. There was considerable skepticism in our minds about the propriety of this type of suture because it has long been wisely preached that in blood vessel surgery intima should be sewed to intima. In this operation it is technically impossible to suture the posterior row intima-to-intima. Microscopic study of sections cut from the walls of the anastomotic channels produced in dogs indicates that it is unnecessary in aortic-pulmonary anastomosis to appose the

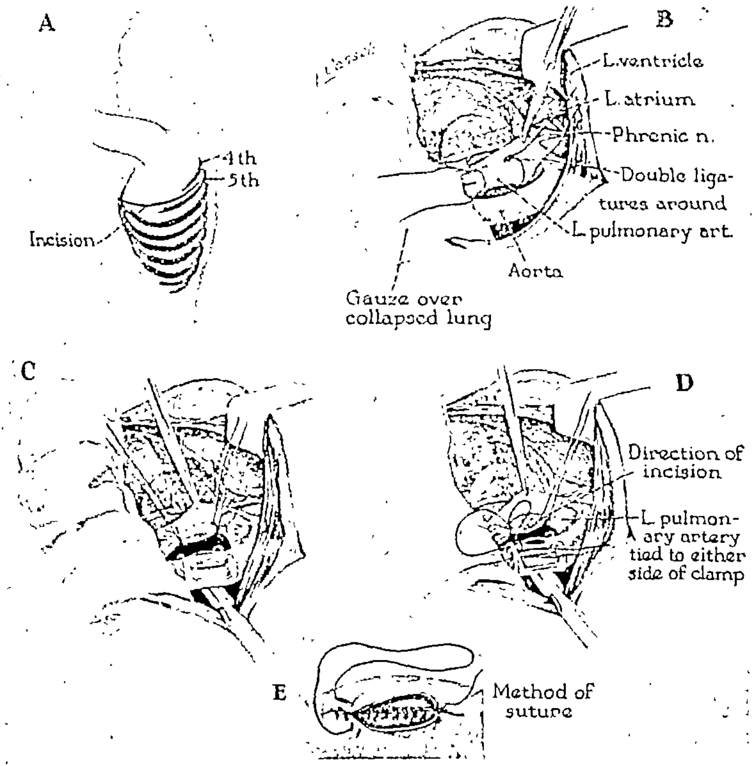


Fig. 2.—Technique of aortic-pulmonary anastomosis.

the vessels intima-to-intima. The difference in blood pressure in the aorta and the pulmonary artery is so great that the constant strong flow of blood through the new channel will keep it open. Within a short time a surface clot is formed over the rough edges and the exposed silk. This layer of fibrin in turn is rapidly covered with endothelium. While I do not wish to say that intima-to-intima suture in general is not preferable, I do not believe that it makes any difference in this operation where the differential in pressures is so great (Fig. 3). In all of the children who have survived surgery, there has been a persistent soft murmur in both systole and diastole indicating that blood is continually flowing through the newly formed channel.

The patient with a left aortic arch is laid on the operating table on the right side and the chest is opened by an incision through the left fourth interspace. A patient with a right aortic arch is approached from the right side through a similar incision. Ample exposure is obtained without resecting or cutting any ribs. The left or right pulmonary artery, as the case may be, is freed from the hilus of the lung. The left pulmonary artery is longer than the right and does not divide into branches as near the main pulmonary artery as does the right. At the beginning of the dissection it may appear in some patients with right aortic arches that the pulmonary artery is too short for a suitable anastomosis to the aorta. Persistent dissection proximally to the pericardium and meticulous freeing of the adventitial adhesions allow adequate mobilization of the pulmonary artery. Thus far we have encountered no instance in which an anastomosis was technically impossible, provided the pulmonary artery was of sufficiently large caliber. In four patients with right aortic arches successful anastomoses were performed. The tremendous variations in the caliber of the pulmonary arteries from normal size to a few millimeters in diameter are unpredictable preoperatively. If the pulmonary artery is less than 3 or 4 mm. in diameter, anastomosis will be difficult and the wisdom of attempting it will be questionable. The small tortuous veins overlying the pulmonary artery and aorta in practically all cases must be dissected off. This not infrequently occasions slight oozing of dark blood which obscures the field. We have discontinued the use of sponges in the chest because they cause trauma and fail to pick up the blood caught in the meshes of loose adventitia. Instead, with a 50 c.c. bulb syringe, physiological solution of sodium chloride is forced in a stream over the operative site and is removed by suction. This procedure not only washes away the excess blood but brightens the structures and makes possible their identification. After the pulmonary artery has been identified and well freed from its bed, doubly encircling ligatures of fairly heavy silk are placed around the proximal and distal portions and about any intervening branches. These ligatures are well oiled to prevent them from sticking to the adventitia. The ligatures are left loose and laid aside while the aorta is exposed and dissected from its bed. A fairly heavy layer of adventitia is left attached to the aorta so as not to interfere with its adventitial blood supply. The number of intercostal arteries requiring ligation and cutting varies greatly from one to twelve. The average is about five.

The medium-sized clamp previously described is used for most patients. The small clamp has been used on children below one year of age; the large clamp on one child 12 years of age. The anastomosis will be simpler technically if a fairly large lip of aorta is clamped off. Palpation of the aorta distal to the clamp will reveal a definite thrill if sufficient blood is going through after the clamp has been tightened.

The incision in the aorta is made from 5/16 of an inch (8 mm.) to 4/16 of an inch (6.3 mm.). In each case the opening is carefully measured with a caliper. In the last six patients we have made the incision in the aorta 4/16 of an inch (6.3 mm.). Since the immediate postoperative results have been just as good as in those patients who have a larger opening, we are naturally inclined for the moment to continue with the smaller incision. The anastomotic channel should be large enough to relieve cyanosis but not large enough to embarrass the heart. What the optimum diameter of the newly formed ductus arteriosus should be can only be determined by the study of patients postoperatively over a period of years. In one child, extremely cyanotic, with a red blood cell count above 10,000,000 the incision in the aorta was made 6/16 of an inch (9.5 mm.). Although the child has been completely relieved of all visible cyanosis the very loud "humming top" murmur makes us fearful that in the course of years she will have difficulty because of excessive strain on the heart. However, to date there has been only the usual moderate amount of cardiac enlargement seen in all patients postoperatively.

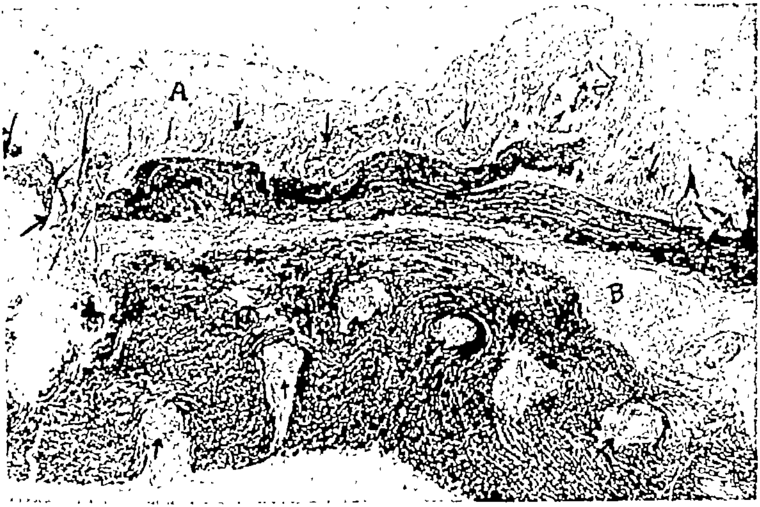


Fig. 3.—Microscopic section, Verhoff's stain, magnification ×60, taken from anastomotic channel 8 days after aortic-pulmonary anastomosis in a dog. The section is cut transversely from the posterior edge of the anastomotic channel where the vessels were sewed together adventitia to adventitia. *A*, Intima. *B*, Adventitia. The elastic tissue in the media is stained black. The upper layer is the pulmonary artery and the lower layer is the aorta. Note that the silk sutures (indicated by arrows) are buried and completely covered with intima.

A slight modification in tying the pulmonary artery to the clamp has been made and it simplifies the technique (Fig. 2, *D*). Instead of tying the pulmonary artery to the anterior lip of the clamp only, one end of the ligature is carried through the posterior lip of the clamp first and then through the anterior. The other end of the ligature is threaded through the same lips in the opposite direction. This brings the pulmonary artery to the aorta in better position for anastomosis. The ligatures are drawn snug and tied while the assistant presses the pulmonary artery against the clamp with a right angle forceps. The ligatures not only shut off the blood supply but also hold the pulmonary artery in position for anastomosis.

The cut in the pulmonary artery is made a little smaller than the cut in the aorta because during suture it tends to stretch. The anastomosis is made with fine 5-0 Deknatel arterial silk on a No. 9 curved atraumatic needle employing a continuous over-and-over running suture. The method of sewing has not been changed. Upon release of the ligatures and clamp, there has been very little bleeding from the suture line. Except in one case in which there was brisk bleeding at the lower angle of the anastomosis, no extra sutures have been necessary. The clamp was reapplied and the bleeding stopped with one suture. Palpation of a thrill at the anastomotic channel gives comforting reassurance that blood is flowing through the new channel into the pulmonary artery.

Upon completion of the anastomosis, the lungs are carefully re-expanded by the anesthetist. A drainage tube is put in every patient through a small stab wound between the ribs in the sixth interspace. A Pezzar catheter with all of the tip cut off but the flange is pulled through the chest wall from the inside out and attached to a water seal as soon as the patient is returned to his room. The catheter is left in three days. The policy of putting a drainage tube in the chest in all patients is the result of a death due to tension pneumothorax.

When the operation has been completed and the dressings have been applied, the patient is slowly turned from the lateral to the supine position. Sudden shifts in position have on two occasions caused marked changes in the pulse and blood pressure due presumably to mediastinal shift. As soon as it is apparent that the respiration, pulse and blood pressure have stabilized, the patient is returned to his room and placed in oxygen for twenty-four to forty-eight hours.

To date, aortic-pulmonary anastomosis has been performed on twenty-six patients with pulmonary stenosis (tetralogy of Fallot) and on three patients with tricuspid atresia, a total of twenty-nine patients. There have been four deaths, or a mortality of 13.8 per cent (Table I). The causes of death were as follows: a girl, aged 12, died fifteen hours after operation. Post-mortem examination revealed fresh cerebral thrombosis of the upper portion of the left postcentral gyrus. A scar in the right frontoparietal region was the cause of hemiplegia during infancy. A 20-month-old child died eighteen hours after operation without regaining consciousness. Post-mortem examination revealed an area of softening in the left temporal region. From gross examination to date it is impossible to say whether this is an old or a fresh lesion. The child had had hemiplegia at the age of 15 months. The causes of death were anoxia, shock and cerebral thrombosis (?). The third death in a 4-year-old girl twelve hours after operation was due to tension pneumothorax. At operation an unsuspected tuberculosis was found in the left apex not demonstrable by x-ray examination. Presumably the lung was opened during the process of freeing it from the parietal pleura. Although the lung expanded normally at the close of operation, at postmortem examination it was completely collapsed and the heart had been shifted to the right. In all these patients the anastomosis was intact. The fourth death in a 33-month-old boy occurred three days after operation. During the operation *before* the clamp was applied to the aorta the systolic blood pressure rose to 152 mm. Hg and the diastolic pressure to 120 mm. Hg. Application of the clamp caused a rise in the systolic blood pressure to 162 mm. Hg. Postoperatively he was extremely restless, breathed very heavily and complained of excessive thirst. A presumptive diagnosis of hemorrhage in the hypothalamus was made. Post-mortem examination unfortunately was denied.

Five operations on four patients proved to be exploratory only. One had an Eisenmenger complex not amenable to surgery; the others had such small pulmonary arteries that anastomosis was impossible. Two of the latter died. At post-mortem examination, atresia of the pulmonary artery was found in both cases. All of the blood to the lungs was carried by bronchial arteries arising from the arch of the aorta for the right lung and from the descending portion of the aorta for the left lung.

While the most suitable age for operation is probably between 3 and 7 years, we have performed anastomoses in thirteen children who were below 3 years of age (Table II). Successful anastomoses were performed on two children below one year of age; one four months and one 6 months.

TABLE I. MORTALITY AND RESULTS

Aortic-pulmonary anastomosis performed	
For pulmonary stenosis	
Tetralogy of Fallot	26
Tricuspid atresia	3
Total	29
Deaths	4
Mortality	13.8%
Those who survived surgery	
Markedly improved (cyanosis largely relieved. Patients living fairly normal lives.)	24
Improved (four-month-old child, cyanosis still present when crying.)	1
Total	25

TABLE II. AGES OF ALL PATIENTS OPERATED UPON

AGE	NO.
4 months to 1 yr.	2
1 to 2 yr.	8
2 to 3 yr.	3
3 to 6 yr.	10
6 to 9 yr.	5
9 to 12 yr.	5
Total	33

TABLE III. AVERAGES OF PATIENTS WHO SURVIVED ANASTOMOSIS

	PREOPERATIVE	2 WEEKS POSTOPERATIVE
R.b.c. count	7,030,000	5,620,000
Hemoglobin	20.87	15.6
Hematocrit	64.4	51.
Oxygen saturation of arterial blood	47.3	77.9

EXPLANATION OF PLATE

(Sketches rendered for publication by Lawrence B. Benson)

The plate depicts a series of injected right upper lobes designed to show typical variations of the bronchopulmonary segments. Each specimen is represented by a view of the medial surface of the lobe, its costal surface, and a mediastinal view of the bronchial tree (apex to the left). The specimens have been drawn with the source of light to the upper right. For identification of the ridges on the medial surface, see Fig. 3.

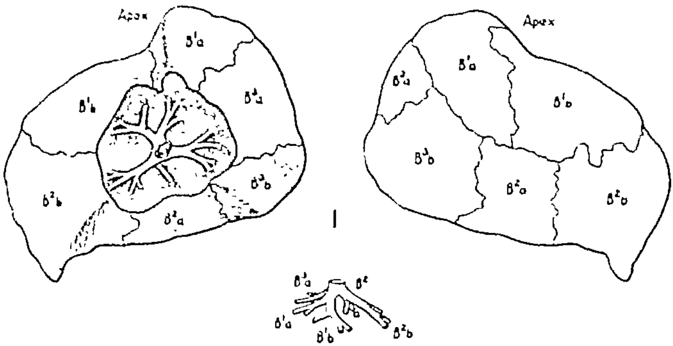
Bronchial pattern:

- *B^1, apical segmental bronchus*
  - B^1a, apical ramus
  - B^1b, anterior ramus
- *B^2, anterior segmental bronchus*
  - B^2a, posterior ramus
    - B^2a1, superior branch
    - B^2a2, inferior branch
  - B^2b, anterior ramus
- *B^3, posterior segmental bronchus*
  - B^3a, apical ramus
  - B^3b, posterior ramus

Fig. 1.—Injected specimen (No. 32) with trifurcate upper lobe bronchus, illustrating (1) the prevailing pattern of the lobe, and (2) some anterior displacement and spreading of the B^1 segment.

Fig. 2.—Injected specimen (No. 26) with V-shaped trifurcation, illustrating (1) an accessory anterior bronchus, BX^1b, (2) the separate origin of the components of the posterior segment, B^3a and B^3b. The latter arises coordinately with B^2 and therefore represents a transition to the ''quadrivial'' type of branching found in 16 per cent of dissected lobes.

Fig. 3.—Injected specimen (No. 21) with bifurcate bronchus illustrating a stage in the separation of the components of B^3. Here B^3b arises coordinately with bronchus B^{1a+3a}. There is also an accessory anterior bronchus, BX^1b. *C.a.*, Crista anterior; *C.i.*, Crista interfissuralis; *C.p.*, Crista posterior; *C. s.*, Crista subclavia.



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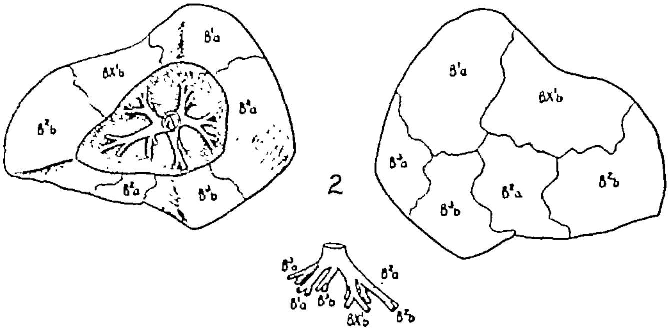

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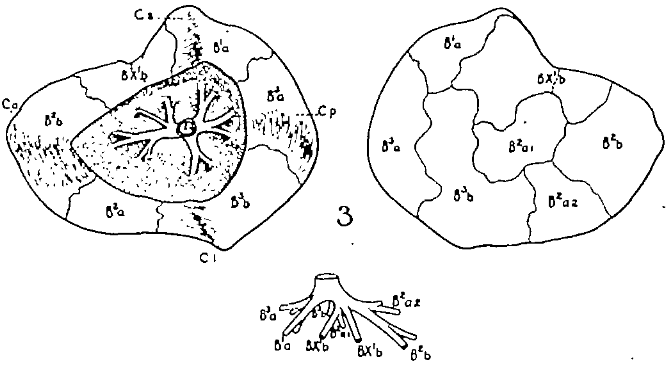

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Figs. 1, 2, and 3.—(*For legend, see opposite page.*)

of an accessory apical-anterior bronchus, BX^{1}b (28 per cent); (2) an anterior rotation or spreading of the apical segmental bronchus (14 per cent); and (3) the separate origin of the two components of the posterior segmental bronchus, B^{3}a and B^{3}b (20 per cent).

1. *The Accessory Apical-Anterior Bronchus, BX^{1}b.*—The specimens depicted in Figs. 2 and 3 have been selected to demonstrate, among other things, the development of a major accessory bronchus, BX^{1}b. The term "X" has been applied to a bronchus which arises as an additional or accessory branch of one segmental bronchus to supply a territory usually served by the ramus of another segmental bronchus. Thus, in Fig. 2 it can be seen that the segmental area of the lobe usually supplied by the anterior branch of the apical segmental bronchus, B^{1}b, is supplied, in this instance, by a large branch of the anterior segmental bronchus, B^{2}. This branch has been designated BX^{1}b.*

Similarly, in Fig. 3 the anterior-apical zone, extending well into the apex, is supplied by BX^{1}b, the accessory branch of the anterior segmental bronchus. In this specimen BX^{1}b gives off a branch that ventilates an area usually supplied by the superior branch of the posterior ramus, B^{3}a1. Accordingly, the designation of B^{3}a1 has been preserved. The rest of the B^{3}a ramus (the inferior branch, B^{3}a2) arises "normally" from the anterior segmental bronchus. (In the left-hand sketch of Fig. 3, B^{3}a2 is labeled B^{3}a, the final "2" having been inadvertently omitted.)

2. *The Anterior Rotation or Spreading of the Apical Segmental Bronchus.*—Although dissection of fifty specimens has shown that in 14 per cent of a relatively large number of lobes, one might expect to find B^{1}b extending far enough down toward the anterior angle of the lobe to take over the territory usually supplied by the upper branch of B^{2}b (cf. Boyden and Scannell, Plate I, Figs. e. and f.), none was found in the present series of thirteen injected specimens. However, Fig. 1 of this article may serve to demonstrate the trend of the variation, in that the area served by the anterior branch of the apical bronchus extends well along the anterior margin of the lobe. However, it does not reach the point which, on the basis of a relatively large number of dissections, we have set as the "normal" inferior limit of B^{1}b—namely, a point two-thirds of the way from the apical-anterior notch to the inferior angle of the lobe.† When B^{1}b extends below this point, it takes over the territory supplied by B^{2}b1, and that ramus is absent. A surface view of such an anomalous spreading of the apical segment may be seen in Fig. 19c. of Brock's monograph.[6]

3. *The Separate Origin of the Components of the Posterior Segmental Bronchus, B^{3}a and B^{3}b.*—The third striking variation found in the analysis of

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*It is interesting to compare Fig. 2 of this paper with Brock's figure 19*a* (p. 24).[5] In the latter a small apical segment is recorded as occupying an anterior-apical zone while most of the apex is occupied by an expanded posterior segment. The pattern of the two figures agrees so well in essentials that it seems likely that what he has called the apical bronchus—probably on the basis of its being the more anterior of two main ascending trunks—we would call an accessory branch of the anterior segmental bronchus. The true apical bronchus, B^{1}a, as determined by the area ventilated, would seem to arise in conjunction with part of the posterior segment.

†The notch in question is that indentation which is caused by the first rib and marks the transition between the apex and the anterior margin of the lobe. Although in many specimens it may be a relatively shallow incisure, it is generally definite enough to serve as a reference point.

fifty dissected specimens was the separate origin of the components of the posterior segmental bronchus. (This occurred in 20 per cent of the lobes dissected.) The specimen depicted in Fig. 2 demonstrates this variation. In this instance the upper lobe bronchus bifurcates, although a study of the keel in the orifice shows that the branching is a modification of the type designated by Appleton[1] as a "V-shaped" trifurcation, i.e., more like the type found in the left upper lobe. The three components have been interpreted to be $B^1a^{+3}a$, B^3b, and B^2 (with its accessory branch BX^1b). If the branching of the lobar bronchus be strictly considered as a bifurcation, then B^3a goes with the B^1a half, and B^3b with the B^2 component. The criterion which identifies this bronchus as B^3b and not B^2a is the position of the main axis of B^3b in the prevailing pattern; for in fifty-four of the sixty-three specimens (fifty dissected and thirteen injected lobes) in which this anomaly did not occur—i.e., separate origin of the B^3 components—the main axis of B^3b lay posterior to the interfissural crest.* Such is the position of the bronchus labeled B^3b in Fig. 2. On this basis, therefore, it could not be considered a B^2a. Furthermore, there is a recognizable B^2a already present in this specimen. Third, in this group of thirteen injected specimens and in the fifty dissected specimens, B^2a has never been found arising coordinately with B^2b at the level of the lobar bronchus.

Another possible interpretation would be to identify the B^3b in question with an independent lateral (or axillary) segmental bronchus which has been described by several earlier writers and more recently by Lucien and Beau.[8] However, in our own and other extensive recent series of dissections the occurrence of such a relatively independent "lateral" segment has been found to be uncommon.[1, 4, 5] Although the clinical implications of the term "lateral" or "axillary" segment might be useful, logically one would have to give separate names to any of a number of subsegmental bronchi whenever they arise at the level of the lobar bronchus. Furthermore, the "axillary" area, as Brock has emphasized, normally receives contributions from two segments, B^2 and B^3, in varying proportions.

Comparison of Figs. 2 and 3 reveals another interesting point in the arrangement of the bronchi of the right upper lobe. While B^3a and B^3b arise independently of each other in both these specimens, they have different relations to adjacent bronchi. In Fig. 3, B^3a is joined with B^1a and forms an apicoposterior trunk suggestive of the left upper lobe. In Fig. 2, however, B^3b has been displaced downward to a degree rarely, if ever, found on the left side; consequently, the specimen represents a form transitional to a new pattern which we have described in 16 per cent of right upper lobes. This is the "quadrivial" type of branching in which B^1 (or B^1a) arises coordinately with B^3a, and B^3b with B^2, the two pairs of orifices being separated by only a shallow keel (cf. Boyden and Scannell, Plate I, Figs. *f* and *i*). The separation of the two components of B^3 thus leads to one of the most striking variations in the bronchial pattern.

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*To be sure, its surface branches may overlap the crest anteriorly. Thus in ten injected specimens, the crest lay within the territory of B^3b, and in two others within the area of B^2a. In the remaining one, associated with an extremely small middle lobe, no crest could be demonstrated.

SUMMARY

A series of thirteen right upper lobes has been studied by differential injection and subsequent dissection of the segmental bronchi. The prevailing pattern of the bronchopulmonary segments, namely, apical, anterior, and posterior, has been described and demonstrated. The three common variations of the segmental pattern have been discussed and illustrative specimens presented. These variations are: (1) the occurrence of an accessory apicoanterior bronchus, BX^1b; (2) the anterior rotation or spreading of the apical segment; (3) the separate origin of the component bronchi of the posterior segment, leading toward quadrivial branching of the right upper lobe bronchus.

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COLLATERAL VENTILATION

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INTRODUCTION

IN AN early period of histology, doubt arose as to the uninterrupted lining of the alveoli (Addison,[1] Rayney,[2] Bakody,[3] Donders,[4] Eberth,[5] and Virchow[6]). Henle[7] drew attention to the fact, that, as a result of this incomplete lining, communications exist between adjoining alveoli by means of "kreisrunde, scharfrandige Oeffnungen" (circular, sharp-edged apertures). On the other hand, with the help of extensive photographical material, Koelliker[8] put forward the opinion that the interstices between the capillaries of the lungs were filled by irregularly formed flat cells, extending over the capillaries themselves. According to Bargmann,[9] this work of Koelliker has been the foundation for all that was taught in hand- and textbooks concerning the lining of the alveoli, for decades.

In the meantime, Kohn[10] showed (with pneumonia patients) the occurrence of fibrinous threads running right through the alveolar wall. In 1894, Miller,[11] from his extensive anatomic studies, concluded that alveolar stomata, if found, are artefacts arising from fixation or by some other means. To this view Laguesse[12] and Oppel[13] later subscribed. At this same time, however, Hauser,[14] Hansemann,[15] Nicolas,[16] Merkel,[17] and Schultze[18] found distinct apertures in the alveolar wall of human beings and various mammals. In 1929, Macklin[19] published an investigation in which he denied the existence of these apertures, but in 1934, on the strength of extensive investigations making use of the latest technical developments, he came over to the opposite view. This author investigated the lungs of human beings from 2½ to 80 years of age, and found the "alveolar vents" much more frequent than had been assumed. Adams and Livingstone,[20] Joannides,[21] and Seemann[22] later confirmed the occurrence of alveolar stomata in mammals and in man, the latter author suggesting the possibility that these stomata might possess some physiologic significance.

The morphologic observations, which indicated the existence of communications between adjoining alveoli, found confirmation in clinical observations and in the results of experiments by van Allen and his collaborators.[23-28] On the clinical side, van Allen, Coryllos,[29-32] and Huizinga[33] have pointed out that, upon obstruction of a bronchus, atelectasis occurs only when access to an entire pulmonary lobe is obstructed in this way. If the obstruction affects only part of a lobe, no atelectasis occurs; therefore, the air must have some roundabout way left by which to enter the obstructed part of the lung. Experiments by van Allen, Lindskog, and Richter and by Kourilsky and Anglade[34] on experimental atelectasis have brought confirmation of this, but have, at the same time,

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made it clear that atelectasis fails to appear only when no inflammation occurs in the obstructed part. Any inflammation, however small, is sufficient to stop the collateral access of air and make possible the development of an atelectasis.

Of the experiments described by van Allen, the most impressive is that which he carried out in collaboration with Jung.[24] A catheter was introduced in a dog, obstructing the bronchus of the lower lobe just past the first bifurcation. The free end of the catheter was kept under water. At every inspiration, water was sucked about 5 cm. into the catheter. At every expiration, however, air bubbled out of the opening of the catheter, and this occurred as long as the experiment lasted. If, on the other hand, the catheter was introduced in such a way as to make the obstruction localized before the first bifurcation of the bronchus of the lower lobe, so that the entire lobe could only ventilate through the catheter, air escaped from the immersed end only once. This, indicated, therefore, that a collateral access of air, outside the obstructed bronchus is possible. A necessary condition is, however, that there is a free communication of part of the lobe with the air outside.

As the existence of the alveolar stomata has been criticized from histologic quarters, so there exists also a possibility that the collateral access of air, here described, is only an artefact. The wall of the alveoli, in between the capillaries, is, doubtless, extremely thin, and proof only against very slight pressure. In his animal experiments, van Allen found that under normal inspiration in the obstructed part of the lobe, a pressure of –5 cm. water occurred. In the clinical cases in which obstruction by a foreign body must have caused a strong tussal stimulus, the difference in pressure between the obstructed and the non-obstructed lung tissue must have been temporarily still much greater. It can be imagined readily that the delicate alveolar wall may break down in some places. All this, however, does not diminish the great importance that collateral access of air undoubtedly can occur in pathologic cases.

Under normal respiratory conditions, the difference in pressure between the outside air and the air in the lungs, according to the calculations of Rohrer[25] and according to the experiments of Bayliss and Robertson[26] amounts to only a few millimeters of water, so the difference in pressure between contiguous lobuli must be still less.

In order to ascertain whether, during normal respiration, the existence of a collateral ventilation by the side of bronchial ventilation of the lungs must be assumed, it is necessary to keep the differences in pressure on both sides of the alveolar wall extremely small. Starting from van Allen and Jung's experiments described above, we have tried to verify in this way the existence of collateral ventilation during normal respiration.

METHOD

The experiments were made on rabbits in urethane narcosis (1 gr. per kg.). The small diameter of the bronchial tubes of these animals precluded the use of an inflated catheter, as used by Coryllos and others. At the end of a semiflexible catheter *c* (Fig. 1) a hollow cylinder of laminaria *a* was fixed by means of a copper ring *b*. On introduction into the bronchus, the laminaria-cylinder absorbed moisture and began to expand, and the part under *b*, being unable to expand, acquired a funnel shape. The free edge of the funnel pressed into the mucous membrane and provided an airtight fitting; at the same time, however, the opening of the catheter was rendered free of the wall, so that there could be no chance of its getting choked up. The catheter was introduced by means of a tracheotomy opening, with the help of the bronchoscope, after Brünings. When the end of the catheter had been brought to the place determined beforehand, a few minutes' interval was allowed for the laminaria cylinder to swell, in order to fix the catheter, then the bronchoscope tube was withdrawn. On completion of the experiment, both the position and the fitting were variably examined in the excised lungs.

By means of the catheter *A* (Fig. 2) and the rubber-tube fixed to it, the part of the lung thus cut off was connected with the air chamber of the bottle *B*, which was partially filled with water. Further connections existed between this chamber and the optic manometer *F*, and the electromagnetic valve *D*, the latter regulating the connection with the volume-recorder F. The manometer, recently described by us,[37] had an excursion of 1 cm. for 0.38 cm. water pressure, the volume recorder gave 2.1 cm. on the photographic paper for every cubic centimeter.

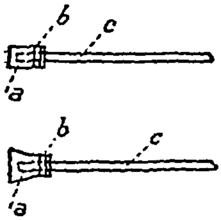


Fig. 1.

If, on inspiration, the valve *D* were shut, a negative pressure would develop in the system, the height of which would, breath excursions of the test object being equal, depend on the volume of air present in the bottle *B*. This volume was adjusted before each experiment by means of the bottle *C*. Now, if, at the beginning of expiration, valve *D* were opened, the volume-recorder would be sucked in if pressure in the system were still below the atmospheric pressure, but after that it would rise to the original position. If, however, collateral ventilation did exist, air must have entered during inspiration, as a result of the difference in pressive between the cut-off part of the lung and its surroundings, and during expiration when the pressure in the system equaled that of the atmosphere, this air must have escaped toward the volume recorder, *S*. For a quantitative measurement of the extent of collateral ventilation, it was necessary that the valve *D* be shut exactly at the beginning of each inspiration and opened at the beginning of each expiration. For this purpose, the abrupt fluctuations which the negative thorax pressure shows at the beginning of in- and expiration lent themselves excellently.

For this, the pleura cannula, as described by Dirken and Heemstra,[38] was used mostly in the right half of the thorax and connected with the water manometer *G*. In the short leg of this manometer lay a small plug of cotton wool *h*. This plug, pressed upward or downward by the very first movements of the water column on inspiration and expiration, closed or opened a mercury contact by means of a lever. The contact point had an excursion of only a few millimeters; the plug of cotton wool was small enough to let the water pass at a further excursion of the water column. Through the interconnection of the relay *M*, the valve *D* was operated by the mercury contact.

RESULTS

A. *Model Experiments.*—In order to get an insight into the value of various factors that may play a part in collateral ventilation, a number of model experiments were made. For this purpose the same apparatus was used, but the experimental animal was replaced by a small, electrically driven pump, while

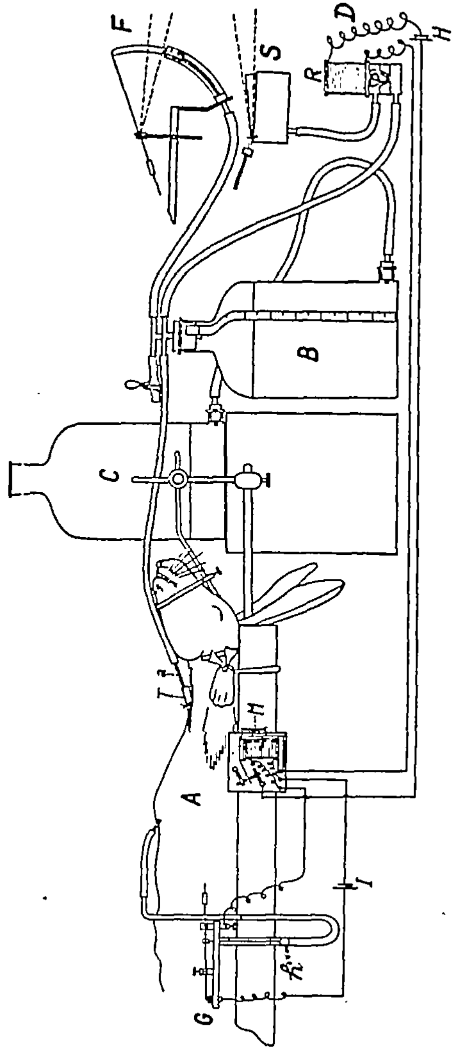
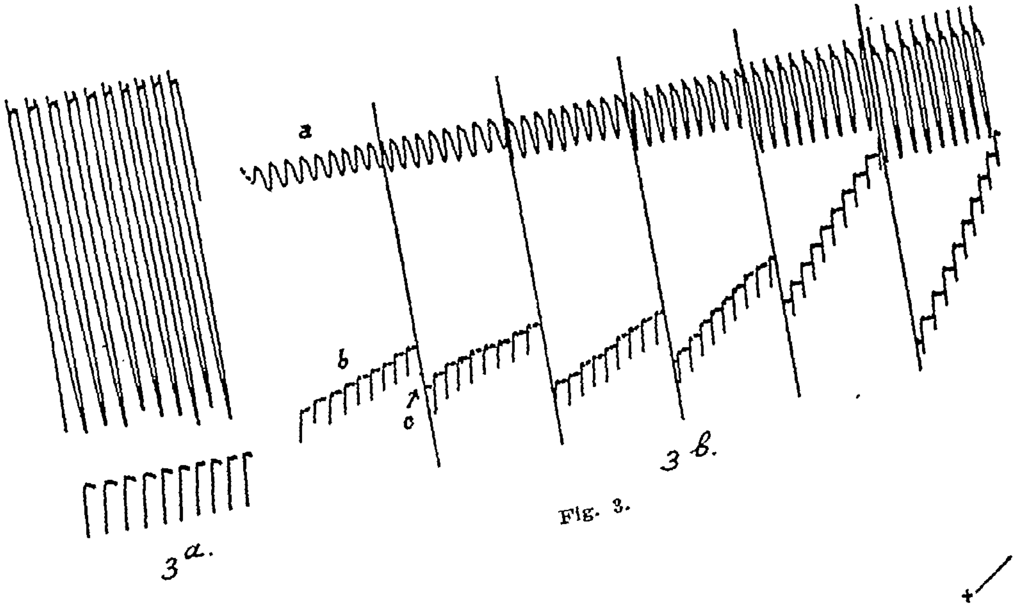


Fig. 2



3a.

3b.

Fig. 3.

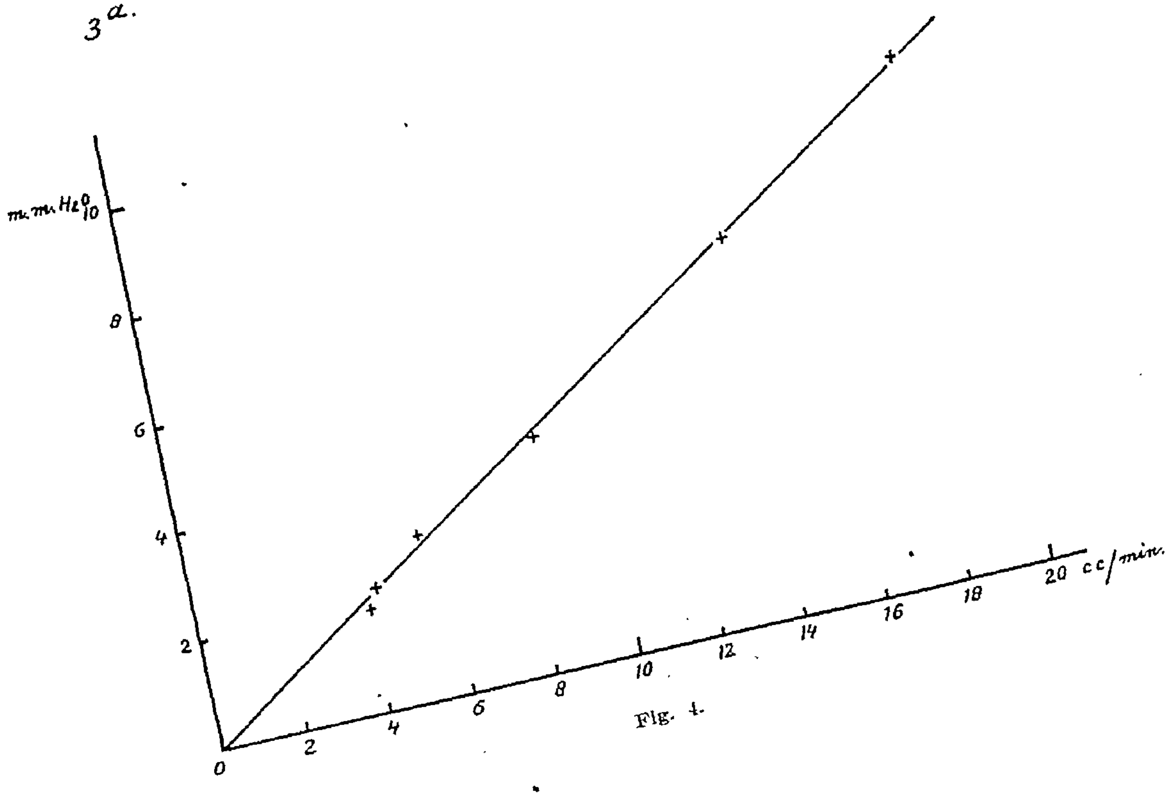


Fig. 4.

the valve *D* was operated by means of a sliding contact on the crankshaft of the pump. Fig. 3, *A* gives a representation of a curve thus recorded, which was taken with a small air content of the bottle *B*, so that large fluctuations of pressure were the result (upper curve). As the quantity of air in the system does not increase or decrease, the volume recorder (lower curve) remains at the same level. This condition would exist, according to van Allen, in the ventilation of the pulmonary lobes, as these do not possess a communication with other parts of the lung outside the bronchi.

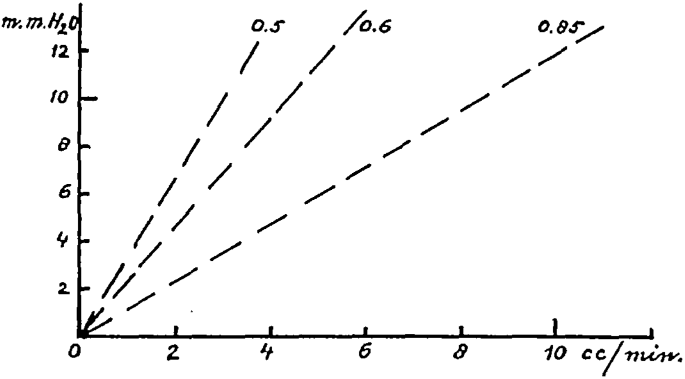


Fig. 5.

The collateral ventilation was imitated by placing a capillary side tube between the pump and the end of the catheter, so that by this narrow communication the system was in contact with the air outside. A number of recordings were made with differing air contents of the bottle *B*. In Fig. 3, *B*, the decreasing air content of *B* from the increase of the negative inspiration pressure in successive experiments may be seen. At the same time, it is evident, however, that more air is sucked in collaterally through the capillary as the negative pressure during inspiration increases. When the values obtained from this curve are set down in a diagram (Fig. 4), there appears to be a rectilinear correlation between the height of the negative pressure prevailing in the system and the quantity of collaterally sucked-in gas. Increasing the frequency from thirty to sixty strokes a minute gives no changes in the quantity of air sucked in collaterally. An increase of the stroke volume causes an increase of the quantity of gas sucked in collaterally, because with one and the same content of the bottle B the height of the inspiratory negative pressure depends on the stroke volume. The collateral gas supply is mainly determined by the resistance (by the diameter of the capillary used) as appears from Fig. 5, where capillaries of a diameter of 0.5, 0.6, and 0.85 mm. have been compared.

From this figure it is clear, moreover, that if the resistance of the communication should change with the differences in pressure, the resultant line should not be straight but curved.

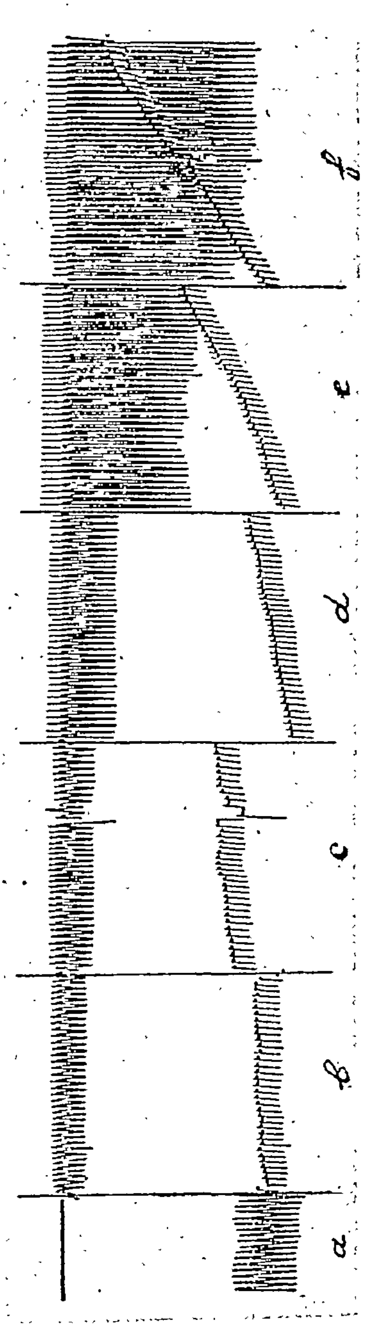


Fig. 6.

B. *Animal Experiments.*—In some twenty experiments, the laminaria end of the catheter was introduced into either the right or the left bronchus of the lower lobe, past the upper bifurcations to the lower lobe with the help of a bronchoscope. After the laminaria funnel had expanded, the cut-off part of the lung was first connected directly with the volume recorder so as to ascertain the degree of ventilation (Fig. 6, *a*). Next, the catheter was connected with the apparatus represented in Fig. 2, and recordings were made, the air content of the bottle *B* being reduced each time (Fig. 6, *b*-*f*). It is evident that the content of the volume recorder increases more quickly as the difference in pressure developing during inspiration between the cut-off part of the lung and its surroundings increases. Since the apparatus was tested for leaks before the experiment, and as the airtight fitting of the catheter in the bronchi was checked on its completion, the only possibility is that the communication is to be found within the lungs themselves past the end of the catheter. In Fig. 7 the quantity of air supplied collaterally per minute in such an experiment, has been entered against the corresponding inspiratory pressure. In all experiments, these points were found to be grouped about a straight line going through the zero point in most cases; in only a few cases a negative pressure of 2 mm. water was required before collateral suction occurred. Then, too, however, there existed a fixed proportion between gas supply and pressure.

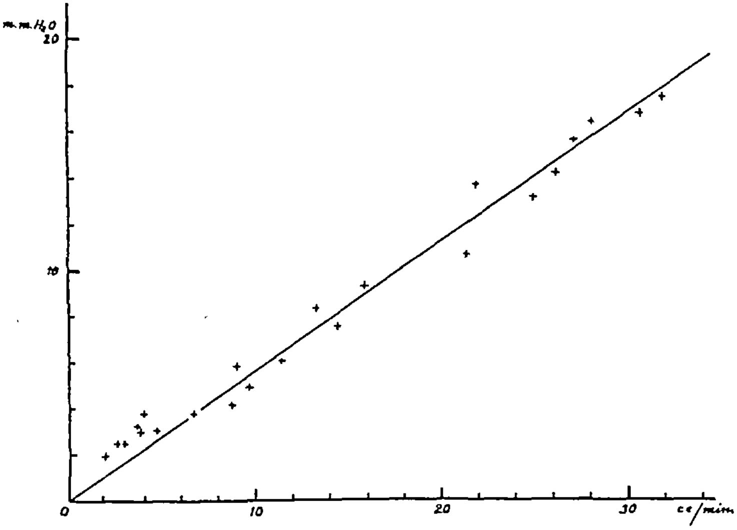


Fig. 7.

In the individual experiments, a large difference in the incline of the line did exist, that is, a difference in the intensity of the collateral air supply at one and the same pressure. This was to be expected, as it is probable that the extensiveness of the cut-off part of the lung and, therefore, the contact with the surrounding tissue, varied in the several experiments. In order to be able to compare the results in some measure, it was supposed that there is a relation between the size of the lung area connected with the catheter and its changes in volume during respiration. For this reason, the breath volume was registered both before and after each experiment (Fig. 6, *a*). It was found that the collateral air supply at a difference in pressure of 20 mm. water amounted to: 37, 39, 41, 33, 43, 36, 36, 44, 45, 37, 43, 40, 36, 44, 47, 42, 33, 34, 37, and 44 per cent, respectively, in the several experiments, with an average of nearly 40 per cent of the breath volume. When the slightly greater pressure difference of 35 mm. water was attained, the volume of the collateral ventilation even amounted to 65 to 66 per cent of the normal ventilation through the bronchus.

When the valve *D* was made to shut off the access to the volume recorder during expiration instead of during inspiration, by adjusting the relay *M* (Fig. 2), a positive pressure developed in the system during expiration. At every inspiration the volume recorder dropped, so that a discharge of gas by the collateral communications was also possible. This discharge turned out to be the exact image of the described increase when inspiration was obstructed.

An entirely different result was obtained if an entire lobe was connected with the system. In most cases the cardiac lobe was used for these experiments, a lobe which, in rabbits, lay entirely isolated in the mediastinum, against the bottom of the heart. For comparison, the entire lower lobe, either right or left, was obstructed in some experiments. Sixteen experiments were made in this way, all, except in cases to be discussed separately, yielding the same result. In none of these cases could any collateral access or discharge of gas be discovered, and both at lower and higher pressure the curve conformed to the model curve represented in Fig. 3, *a*. This negative result was of special significance, moreover, as in this way it was demonstrated that the fixing of the catheter in the bronchus and the rest of the apparatus was airtight, and that the rising or dropping of the volume recorder found on shutting off a part of the lobe did not arise from leakage but from communication in the lung tissue itself.

In three cases, however, notwithstanding that the entire cardiac lobe had been connected, an access of air, however slight, was observed. At a pressure of 20 mm. water, this amounted to only 2.7, 4.1, and 3.6 per cent of the breath volume, respectively. In view of the results already mentioned, this indicated the presence of connections with other lung tissue, and on histologic examination,* it turned out that in these three cases there existed a bridge of lung tissue between the cardiac lobe and the right lower lobe. In none of the experiments yielding a negative result was such a bridge of tissue discovered.

These results indicate that the component parts of a pulmonary lobe communicate outside the bronchi, and that a similar communication does not exist between the different pulmonary lobes themselves, unless these are connected by a bridge of lung tissue. Some experiments were conducted in order to ascertain whether the width of the collateral communications could be influenced.

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*We owe thanks to Prof. de Haan for his ready help in this and the remaining histologic work in this investigation.

Cutting or stimulating the vagus and the sympathetic nerve had no effect, no more had the cutting of the phrenic nerve when pectoral respiration took over the function of the diaphragmal respiration normal for rabbits. In all these cases, the extent of the collateral air supply was determined solely by the negative pressure developing in the system during inspiration. This also held good for the respiration changes caused by breathing mixtures rich in carbon dioxide and those caused by a partial stenosis of the bronchial tubes.

DISCUSSION

The experiments here recorded confirmed the results obtained by van Allen and his collaborators concerning the existence of communications between the component parts of a pulmonary lobe. In the model experiments, it has been shown that the quantity of gas sucked in collaterally was directly proportionate to the negative pressure if the width of the capillary leak remained unaltered (Fig. 5). In the animal experiments, we found in the same way that the quantity of gas sucked in collaterally was directly proportionate to the negative pressure (Fig. 7) and from this we may conclude that here, too, the total width of the communications has remained unchanged. *From this, it follows that the communications meant cannot be fissures of tissue, because their permeability does not increase with increasing pressure.* The observation that these communications were open even at the most minute differences in pressure, leads to the conclusion that these permanent communications also have some significance for normal ventilation of the lungs. The ventilation of a lobulus of a pulmonary lobe may also take place apart from ventilation by its proper bronchus, by means of collateral ventilation from the adjoining lobuli.

This collateral ventilation will certainly come into operation if even minute differences in pressure arise in contiguous lobuli during respiration; in this way, a balance of pressure is effected, and at the same time the uniform constitution of the contents of a pulmonary lobe is promoted. From our results, it also appears that as regards its extent, this collateral ventilation may become very considerable. As has been stated, the collateral access of air at a difference in pressure of 2 cm. water, amounts to 40 per cent of the quantity that is normally supplied by the bronchi. This is true, while of the entire lower lobe, only the upper branch of the bronchus is connected with the outer air, so that the area of contact is small in proportion to the volume. This is the reason why rabbits, at least, may be expected to possess numerous open communications between the lobuli of a pulmonary lobe.

The existence of anastomoses between the finer ramifications of the bronchi has not been described in the literature, but, on the other hand, the histologists have occupied themselves with the existence of communications between adjoining alveoli. The existence of alveolar stomata has been confirmed recently by various investigators, although doubt still prevails as to the number and nature of these communications. Moreover, alveolar stomata have not yet been demonstrated in rabbits. We have examined the lungs of some of our experimental animals for them. Contrary to the usual way of fixation, and in order to preserve the normal condition as well as possible, we allowed the fixation fluid

(Bouin's solution) to flow into the lungs of the living animal at a pressure of not more than 2 cm. water. It was introduced by means of the catheter which, as in the above-mentioned experiments, shut off part of the lower lobe. If the fixation fluid was allowed to flow in at such slight pressure, the lung filled like a sponge; the animal, who had been brought into a heavy narcosis, showed no reaction whatever, probably because both the circulation and the conduction of stimuli were interrupted as soon as the tissue came into contact with the fixation fluid. This also explains why the blood in the left heart was found

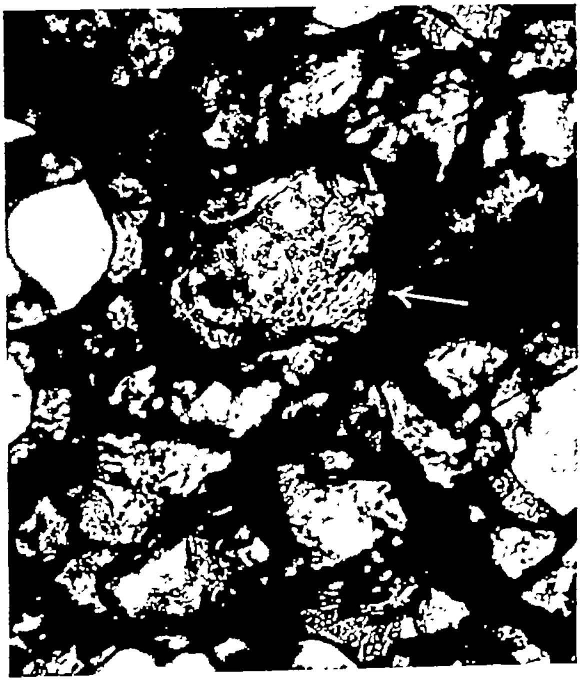

Fig. 8.

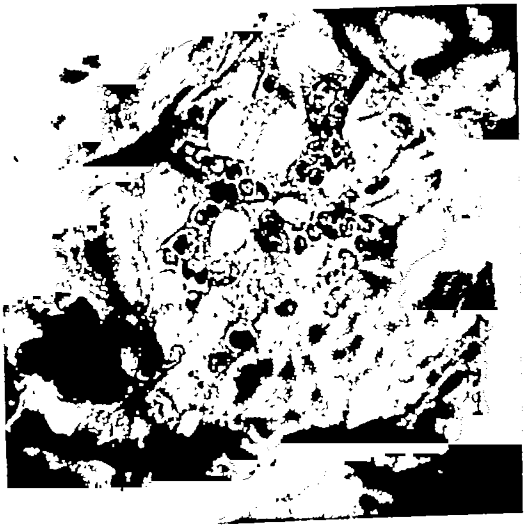

Fig. 9.

to be liquid and not at all discolored at autopsy. This way of fixation had the advantage that the normal expansion of the lungs was preserved and also the normal state of circulation; the pressure applied was so minute that the capillaries, too, remained filled with blood. After preliminary treatment and imbedding in celloidin, sections were cut 50 to 100 μ thick, much thicker than the usual sections. Coloring of the sections was effected by means of hematoxylin-eosin, orcein Mallory, or orcein van Gieson.

Fig. 8 shows a typical general picture of the lung tissue in the slides thus prepared. In the wall of all alveoli that lend themselves to a close observation are found sharply outlined openings which, however, vary greatly in both number and form. The alveolar wall, as may be seen in the alveolus that has been further indicated in the figure, often seems to consist merely of a mass of capillaries which may be clearly recognized as such from the blood cells present in them. This same alveolus has been reproduced much enlarged in Fig. 9. In Fig. 10, a single stoma of another alveolus has been brought into focus. It appears clearly from this photograph that only capillaries form the border of the stomata. The fact that the stomata are only meshes in the capillary network is most clear in binocular observation, where the entire dome of the alveolar wall may be followed. The occurrence of numerous stomata in the lungs of birds and some minor mammals (bat) has already been described by others. Our sections show that an all-around ventilation of the lung capillaries with air exists also with larger mammals. That this could be demonstrated is probably due to the method of fixation in vivo, preserving the normal expansion and the normal filling with blood. Not much could be perceived of a spanning of the stomata by elastic fibers, as described by a few investigators (Macklin[10]). Upon staining with orcein, van Gieson, elastic fibers could be seen here and there, but their course was irregular and in no way connected with the limits of the stomata.

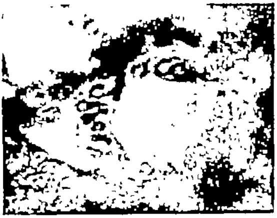

Fig. 10.

These stomata were found in every section. Their size varied and depended on the width of the meshes of the capillary network. Their form, too, varied much, being sometimes a true circle, sometimes not more than a slit. It is quite possible that their form is mainly determined by the filling of the lung capillaries with blood. Here and there a few cells could be found in the meshes of the capillary network which lay outside the capillaries.

From these microscopic observations it is clear that in the alveolar walls of rabbit lungs, a large number of stomata exist. These findings agree with the results of the experimental part of this investigation, and explain how a collateral ventilation of the lung tissue is possible. Outside the bronchi, the air can escape through the stomata from alveolus to alveolus and even further, as the partitions of connective tissue in between the acini, lobuli, and the larger parts of the lobes are no more than wide-meshed nets. The ample degree to which these interalveolar communications exist explains the large gas transport that could be demonstrated in our experiments and, at the same time, stresses the importance collateral ventilation must have for maintaining a balance of pressure in the lungs and for the uniform composition of the air in the various parts of a pulmonary lobe.

SUMMARY

In rabbits, all parts of a pulmonary lobe communicate outside the bronchi, so that transport of considerable quantities of gas is possible.

The width of the communications rendering this collateral gas transport possible is independent of the difference in pressure between two parts of the lobe, so that we must assume that the communications are open also under normal respiration conditions.

Through these open communications, collateral ventilation may be brought about during respiration, guaranteeing a balance of pressure in the various parts of a pulmonary lobe and promoting a uniform constitution of its content. Between the pulmonary lobes as such these communications do not exist, unless they are connected by a bridge of lung tissue.

From a review of histologic literature and from microscopic observations, it is rendered probable that the alveolar stomata must be considered as the communications responsible for the collateral ventilation.

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COLLATERAL VENTILATION IN MAN

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INTRODUCTION

IN AN earlier communication by Baarsma and Dirken,[1*] it was demonstrated that there exists a collateral ventilation of the lungs in rabbits. This had first been described in dogs by van Allen and his collaborators.[2] When a side branch of a lobe of the lung is disconnected, this part is still ventilated to a considerable extent because the air can circulate via a normally operating bronchus and the alveolar vents. These vents, the existence of which has been established by many investigators, can be made convincingly visible by a special method of fixation. A quantitative determination of collateral ventilation was first made in rabbits. Collateral ventilation proved to appear even with very small differences in pressure between the connected and disconnected parts of the lung, that is, with pressure differences of slightly more than 2 mm. water. Collateral ventilation, therefore, must be of importance in physiologic as well as pathologic circumstances. The air content of a special part of the lung was measured with normal and with collateral ventilation. When a branch of the lung was obstructed, it appeared that there was an average ventilation of 66 per cent of the normal (a considerable percentage) due to collateral ventilation.

When collateral ventilation had been demonstrated in two mammals, the next step was to see if it existed in man. We had been suspecting this for a long time, because of certain patients who had been observed in the clinic. Patients with a foreign body in one of the deeper respiratory passages are of particular importance in this respect. These patients often become experiments in vivo, so to say, in which it may be assumed that suddenly a certain bronchus of a hitherto healthy lung is disconnected. The exact localization of the obstruction can be determined by means of radiologic examination and bronchoscopy. In the case of a complete obstruction of a main bronchus or a lobar bronchus, there is always atelectasis. We had, however, been struck by the fact that in some patients where the bronchus was obstructed at a deeper point, notably beyond the first division of the bronchus of the lower lobe, there was no atelectasis. There is thus a very sharp contrast between cases where atelectasis can, and cannot be demonstrated.

This is most obvious in the following cases, which have been the starting point of our investigations. In both patients studied a metal foreign body had been aspirated on the left side. These metal objects are especially suitable in these cases because they can be localized easily by radiography, and because they are not so likely to cause an inflammation and thus obscure the syndrome.

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*Page 238, this issue.

CASE 1.—A girl 10 years of age aspirated a small metal object ten days previous to our examination. She had a violent fit of coughing, and kept coughing, with occasional dyspnea. The left thorax obviously lagged behind in respiration. In percussion, a strong dullness was noticed on the left side, especially over the lower lobe. On the left side the breath sounds had almost disappeared. On the radiograph of Fig. 1, the metal object was conspicuous on the left side; trachea and bifurcation were visible; the foreign body appeared to be located in the left lower section of the main bronchus and in the first part of the bronchus of the lower lobe. There was a strong dislocation of the mediastinum to the left, and to the right a "naked" vertebral column was visible.

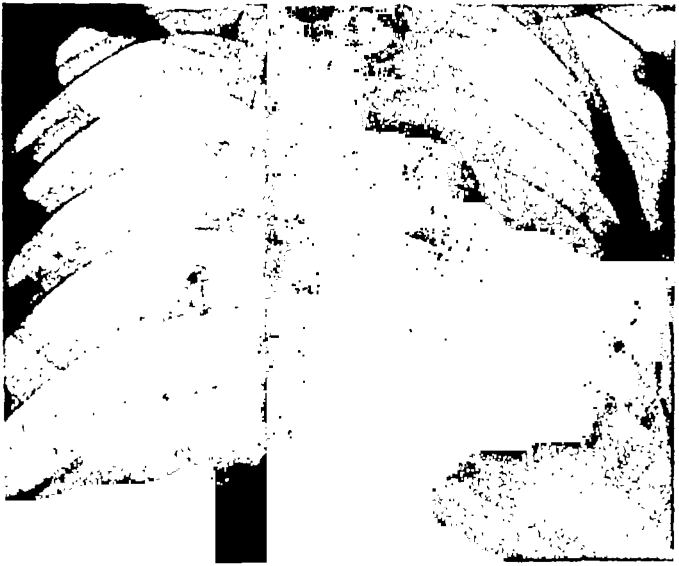

Fig. 1.

The radiologic localization of the foreign body was confirmed by bronchoscopy. It was located in the lower part of the main bronchus and the upper part of the bronchus of the lower lobe, and obstructed the whole of the lower lobe by its somewhat broader lower end. The object was extracted. The child recovered completely, after there had been symptoms of inflammation in the atelectatic left lower lobe.

The radiograph of Fig. 1 is very typical of an atelectasis of the left lower lobe, there is a very homogeneous shadow, the so-called "ground-glass shadow" of van Allen.

CASE 2.—A boy, 2 years old, had aspirated a metal pellet five days before examination. There was severe dyspnea immediately after the accident, which soon passed off. As the child kept coughing, he was sent to the clinic.

When admitted, the child did not appear to be ill. There was no dyspnea, *and the body temperature was entirely normal.* No deviations could be found by percussion, but the breath sound was weaker on the lower left side.

The pellet is clearly visible on the roentgenogram of Figs. 2 and 3. These radiographs have been taken during deep inspiration and deep expiration, respectively. The dislocation of the diaphragm is striking. *There is no trace of atelectasis and there are no symptoms of* *bronchostenosis.* In both radiographs the mediastinum is in its normal position. During respiration it moves neither to the left, as may be expected in a case of total obstruction (Holzknecht's symptom), nor to the right, as is seen in valve stenosis.

It could be assumed on the strength of these roentgenograms that the foreign body was localized deep in the bronchial tree, in the bronchus of the lower lobe. This was confirmed by bronchoscopy. The pellet was located beyond the first dorsal branch of the bronchus of the lower lobe. There was no reaction of the mucous membrane and no sign of inflammation. Further on, the pellet hermetically closed the bronchus of the lower lobe; it was even wedged in so tightly that no proper forceps place could be found, and all attempts at extraction failed. Tracheotomy was performed the next day, after which the pellet was removed through the medium of bronchoscopy, with great difficulty. The diameter of the pellet was 6.5 mm., certainly very large for this part of the bronchus of the lower lobe in such a young child. Extraction was followed by a speedy recovery.

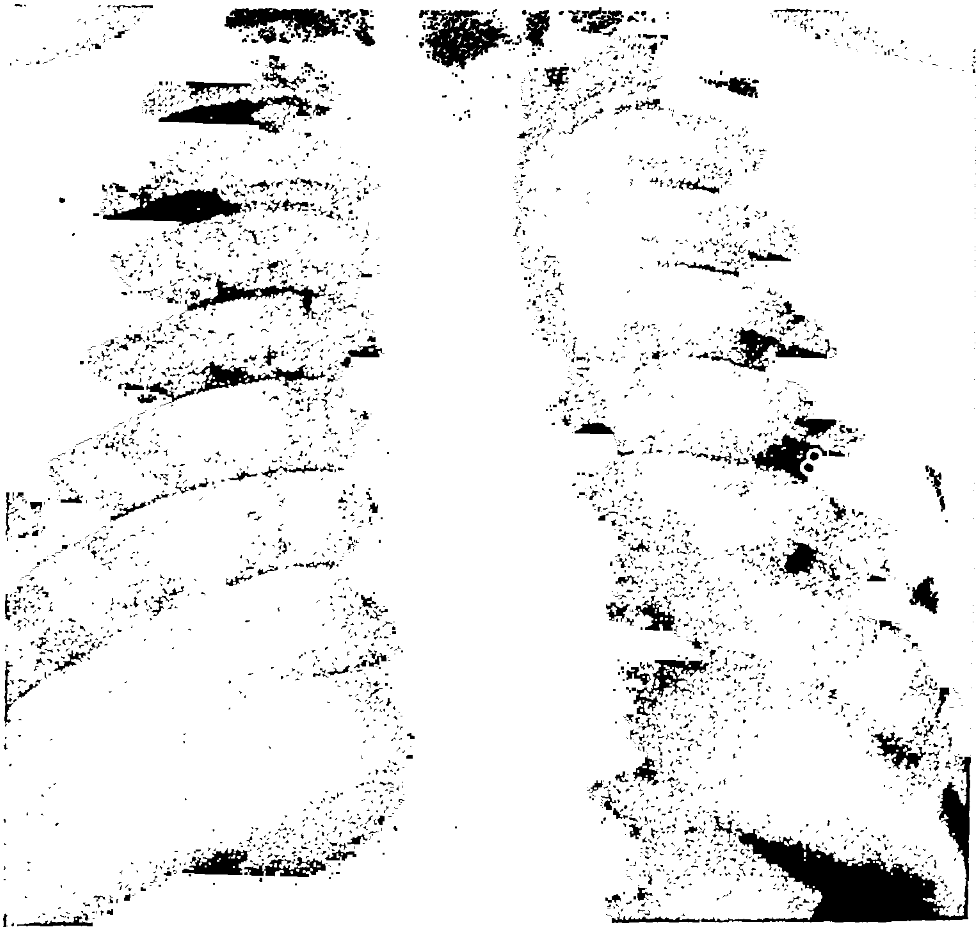

Fig. 2.

Bronchography was made after a few days, and 10 c.c. of lipiodol were introduced; as appears from Fig. 4, the bronchial tree was entirely normal. The bronchogram was important, because it told us more about the exact localization of the foreign body. Figs. 2 and 3 show that the pellet remained practically in the same place, in spite of deep respiration. During expiration there was a slight lateral movement, but on both photographs it is on a level with the eighth rib. It is a well-known fact that, whereas there is a considerable dislocation in the distal parts of the lung during deep respiration, there is only little movement near the hilus and the great bronchi.

Returning to the eighth rib on the bronchogram of Fig. 4, we find that the pellet was localized in the entrance of the bronchus of the lower lobe of the left lung, but far enough down to leave the passage to the great first dorsal side branch free. This first dorsal branch is very large and always present. During the last few years it has been examined by several investigators who described the anatomy of the bronchial tree. We, too, were able to confirm these results.[3] This side bronchus branches off a little higher than the former location of the pellet, almost opposite the fork of the bronchus of the upper lobe.

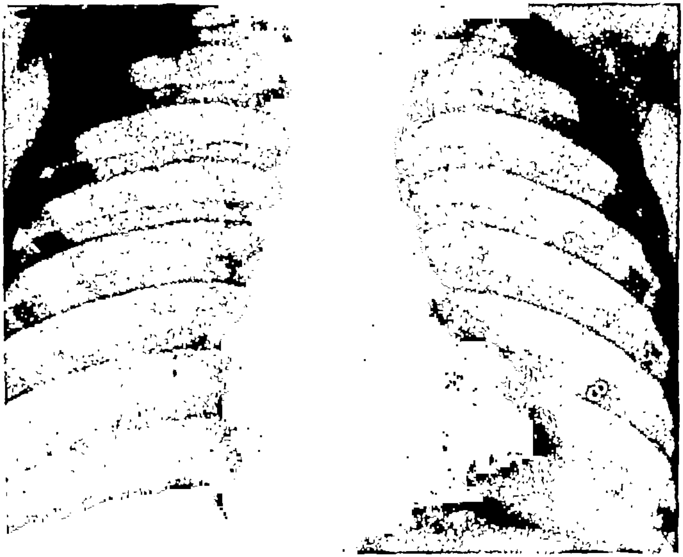

Fig. 3.

Fig. 5 gives a schematic representation of the situation in these two cases. In the first case (Fig. 5, *A*) there was a complete obstruction of the bronchus of the lower lobe, no collateral ventilation and, therefore, atelectasis. In the second case (Fig. 5, *B*) the first dorsal branch was free, and the only possible explanation seemed to be that there had here been collateral ventilation, as indicated by the arrows, so that no atelectasis had developed. It is a curious fact that no symptoms of bronchostenosis could be found. Investigations by Baarsma and Dirken showed that there was so much collateral ventilation in rabbits that this may explain why a considerable new supply of air is possible in man as well, and why there is no dislocation of the mediastinum during respiration. These cases, to which many more from the clinic might have been easily added, rendered the possibility of collateral ventilation in man very likely. In order to make sure, a more direct method to obtain confirmation was necessary.

METHOD

Evidently, only an entirely harmless method could be used when investigating collateral ventilation in human beings. It may even be asked if such experiments were permissible at all. In view of the importance of this problem, we answered this question in the affirmative, especially because the experiments involved no danger to the patient. Investigations have only been made in cases where bronchoscopy was required for other reasons and where the lungs previously had been proved to be perfectly normal. The first patient was an asthmatic who was sent to our clinic for bronchoscopic treatment. We were greatly relieved that shortly after the departure of this patient, another from the same village was admitted, who brought a letter from the local physician to the effect that the first patient had been so pleased with the success of his careful treatment that the second wanted to be treated in the same way. The psychologic factor is of considerable importance with asthma. We have never, however, seen any harmful effects from these investigations.

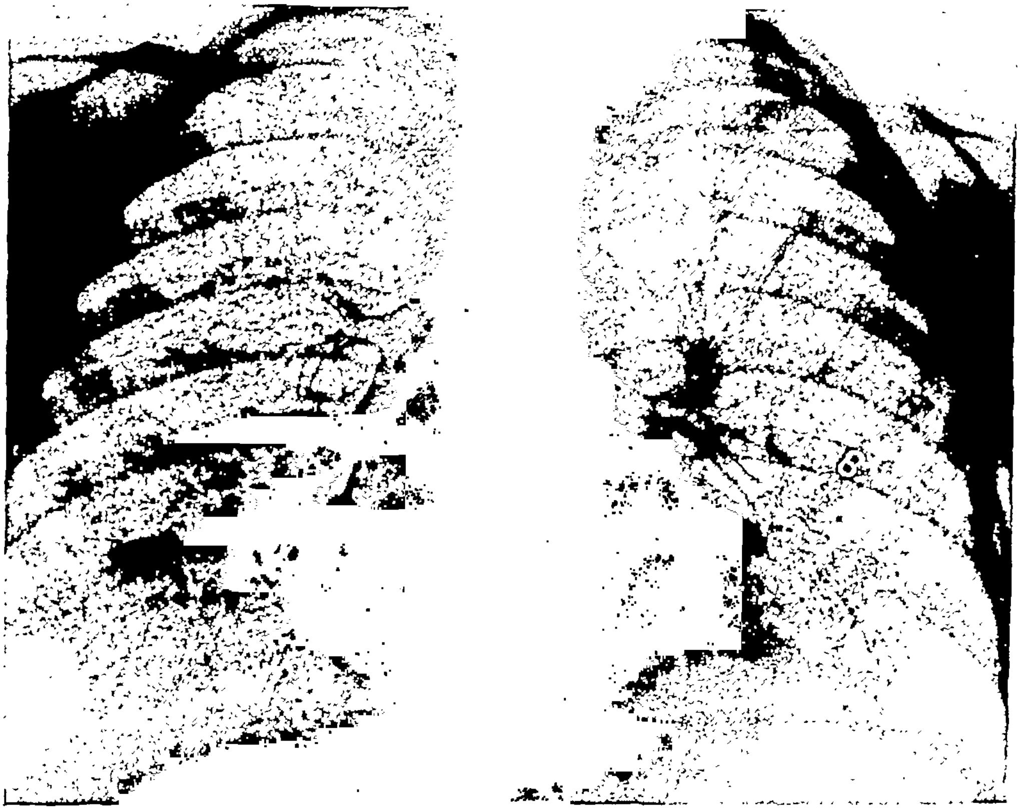

Fig. 4.

In obstructing the entrance to the bronchus, it was naturally impossible to make use of the laminaria cylinder described in a previous publication on experiments with rabbits. We used an inflated catheter, as used by Coryllos and others. It had a small rubber cuff attached to its distal end, which could be inflated. It was filled with a sterile salt solution by means of a very thin rubber tube running through the catheter. When the catheter was well in position and the rubber cuff inflated, the latter hermetically closed the entrance to the bronchus. The catheter could not be withdrawn unless the cut was first emptied, and it moved synchronously with respiration.

The patient was anesthetized by means of pantocain 2 per cent adrenalin, and put on the bronchoscopic table. The bronchoscope (after Jackson) was introduced, and the bronchus into which the catheter was to be inserted was adjusted. The lower lobe was used in all cases; in a number of experiments the catheter was inserted in such a way that the entire bronchus of the lower lobe was obstructed, in other cases only part of a lobe was disconnected by inserting the catheter into the posterobasal or laterobasal side branch of the bronchus of the lower lobe.

The catheter was then connected with the spirometer, which recorded the respiratory movements on a kymograph. A small weight caused a certain negative pressure in the spirometric system, and consequently in the part of the lung connected with it. If, therefore, there were collateral ventilation, air from the surrounding parts of the lung would be sucked into the area of negative pressure and the volume of the spirometer would be increased. This was recorded by a decline of the curve on the kymograph. If there were no collateral ventilation, the volume of the spirometer would remain more or less stationary, and consequently the curve on the kymograph would show a horizontal course. The whole experimental arrangement is shown in Fig. 6.

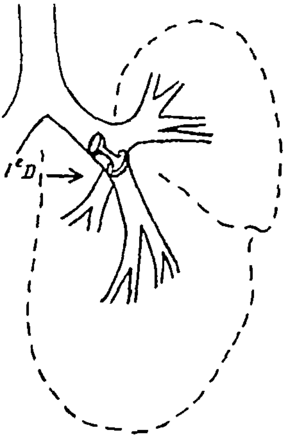

Fig. 5A.

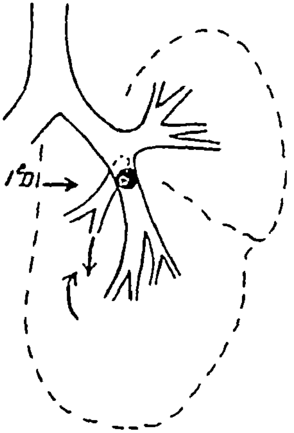

Fig. 5B.

When the whole of the lower lobe was disconnected, there was not collateral ventilation, as might be expected. Fig. 7 gives an instance of such a curve; the left lower lobe of a man of 28 years was disconnected completely. Respiration was recorded with a negative pressure of 0 to 2 cm. water in the disconnected lobe. The curve kept a horizontal course.

Fig. 8 illustrates the experiment with a man 26 years old, who had the catheter in the laterobasal section of the left lower lobe. The fall in the curve was very obvious here and was proportional to the negative pressure which was determined by the weight attached to the spirometer. It followed that collateral ventilation had been proved here. This was also the case in Fig. 9, the curve of a 31-year-old man, where the catheter had been inserted into the posterobasal branch of the left lower lobe. The volume of breath was much smaller here, and the decline of the curve was less. Yet there obviously was a decline of the curve, and consequently an increase of the volume of the spirometer, which increased with the negative pressure.

The same result was obtained on all occasions; there was no fall of the curve when the whole of the lobe was disconnected, but there was a fall when only a side branch was obstructed. *This proves with certainty that there is collateral ventilation in man.* The mechanism can hardly be imagined otherwise than in dogs and rabbits.

DISCUSSION

No doubt, collateral ventilation is highly important, first of all in physiology, as has been described in the preceding publication. It provides an equal distribution of air and the speedy neutralization of even small pressure differences between various adjacent parts of the lung. This collateral ventilation is, however, of far greater importance in pathology. No doubt atelectasis would develop much more frequently without it.

It seems that in classifying atelectasis, the old way is still the best, and that in *acquired* atelectasis we can only distinguish *resorption* and *compression* atelectasis. The latter, which is caused by a passive emptying of the lung, as in the case of an exudate in the pleural cavity or a large tumor, need not be considered further.

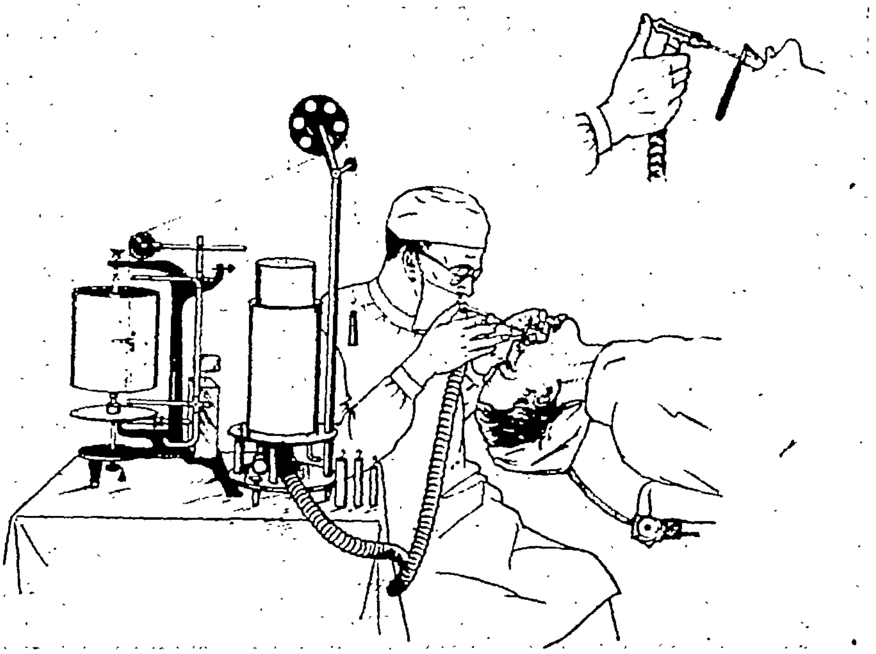

Fig. 6.

Resorption atelectasis develops because, as a result of an obstruction of the bronchus the air disappears from the part of the lung belonging to it. The remaining air is resorbed by the blood in the alveolar capillaries. Notably Coryllos and Birnbaum[4] have made extensive investigations as to how this resorption is effected. Complete obstruction of a main bronchus or a lobar bronchus causes atelectasis; obstruction of a side branch does this only under particular circumstances. We can now state that on the whole these circumstances are determined by the possibility of or absence of collateral ventilation under the given anatomic conditions, or by elimination of collateral ventilation under certain circumstances.

As to the first, it sometimes happens that a certain side branch provides for a segment of the lung which is completely separated from the remainder of the lobe. In our anatomic investigations, for instance, we found that in one out of every ten cases, the first dorsal segment of the lower lobe was defined by a more or less deep fissure. Like other investigators, we found that in a few cases this segment made the impression of a separate lobe (lobe moyen dorsal). Under these circumstances, obstruction of this branch will automatically bring about atelectasis. We see, therefore, that anatomic variations are of considerable importance in this respect.

Collateral ventilation is eliminated (1) by shallow breathing, which minimizes pressure differences between various parts of the lung, or (2) it is eliminated if an inflammation develops in a part of the lung which is not disconnected.

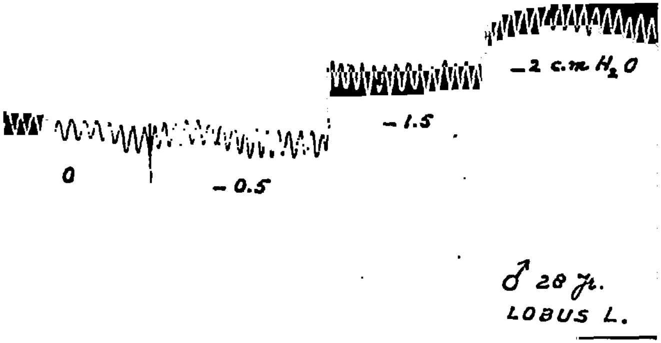

FIG. 7.

The latter could be proved experimentally by van Allen and his collaborators. The two factors will often go together; many patients with shallow breathing have at least a bronchitis. Each inflammatory process in the lung may easily cause obstruction of vents through edema or the presence of fluid or secretion, and consequently impede collateral ventilation. This factor of inflammation probably will be of the greatest consequence in most cases.

Shallow breathing may result from narcosis, or, if breathing is impeded, by pain or paralysis of the respiratory muscles. A great deal has been written during the last few years about postoperative collapse of the lung and traumatic atelectasis, that is, with injuries of the thorax. The mechanism has become much more intelligible, now that we have become acquainted with collateral ventilation. These patients are often suffering from bronchitis; plugs of secretion obstruct the bronchi and when their breathing becomes shallow as a result of pain, collateral ventilation is eliminated and atelectasis arises.

In patients with bronchitis, the presence of collateral ventilation often prevents atelectasis. If, for instance, a side branch of the bronchus is obstructed by a plug of secretion, a negative pressure arises behind the obstruction, which causes collateral ventilation. With a strong negative pressure, the plug will be sucked more firmly into the bronchus. Collateral ventilation, however, keeps down negative pressure and consequently there remains sufficient air behind the obstruction. Thanks to this air, the plug may be removed by coughing. This example clearly shows the importance of collateral ventilation in pro-

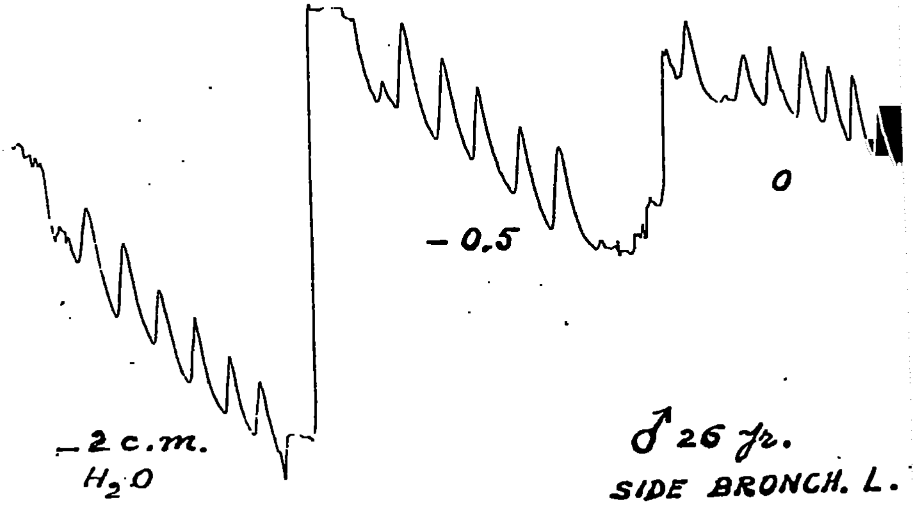

Fig. 8.

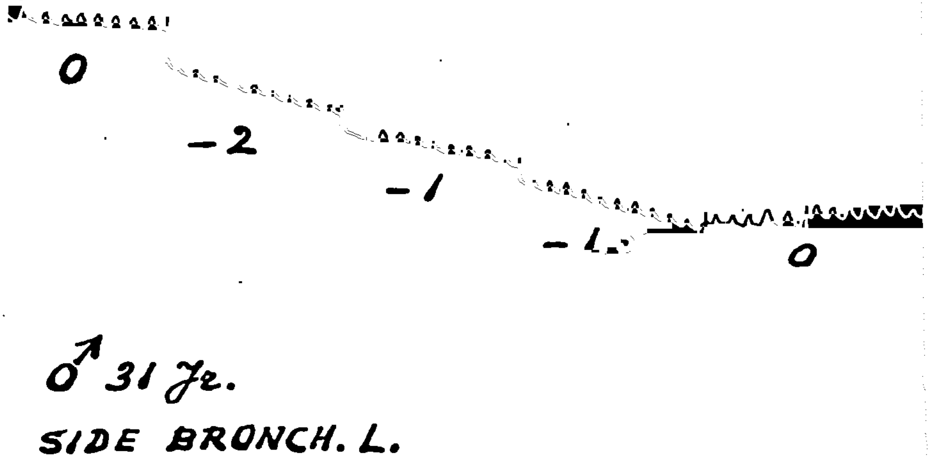

Fig. 9.

moting expectoration and preventing atelectasis, with much inherent mischief. For it is now known that there is only a very gradual transition from atelectasis to pneumonia.

The importance of collateral ventilation is also apparent with stripe-form atelectasis as described by Fleischner[5] and Keyser.[6] It has long been known that patients with widely divergent histories have shown stripe-form shadows on the radiogram, especially on the base of the lung. This was found in: patients with fractures of the ribs; kyphoscoliosis; after operations, especially of the higher abdomen; during coma, etc. Pleurisy was occasionally thought of, Which was supposed sometimes to develop lymphogenously from peritonitis.

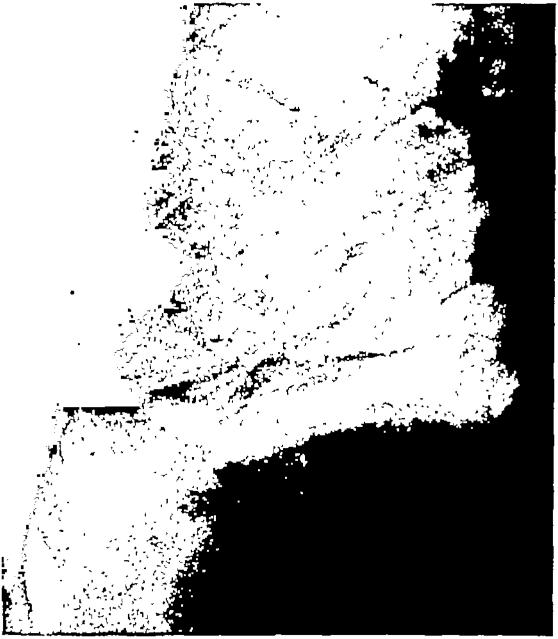

Fig. 10.

Fleischner has been first to give the correct explanation. All these patients have shallow breathing and bronchitis in common. Obstruction of a bronchus causes the collapse of part of a lobe. The thoracic wall and the part nearest the hilus remain in their places. This part of the lung can only contract in a downward direction, and an atelectatic disk develops, which may be seen in the radiogram as a stripe. He called this "gerichteter Kollaps." Keyser was able to confirm these observations. Fig. 10 shows such a stripe-form shadow in a patient with multiple costal fractures. It is now clear that the essential factor in this stripe-form atelectasis is the absence of collateral ventilation through shallow breathing of these bronchitic patients. These shadows disappear when a patient is made to breathe deeply.

It is even more important to prevent atelectasis, especially in view of a possible inflammation of the lungs. In this respect, the prophylaxis has been the common property of each practitioner for many years. He knows very well that deep breathing, the stimulation of expectoration, sitting up in bed, and getting up quickly, especially with older people, prevent a hypostatic pneumonia. Unconsciously, he has thus promoted collateral ventilation. Old experiences have now been given a scientific coloring. It is valuable if the right theoretical explanation can be given for practical facts.

With massive atelectasis of the whole lung or lobe, there is only one important factor, the obstruction of the main bronchus or the bronchus for a lobe. With the very frequent focal atelectasis, there are, consequently, two factors: the obstruction of a side branch and the elimination of collateral ventilation. This does not apply to a specific inflammation only, but also to tuberculosis; Westermark[7] and Roth[8] have demonstrated how easily bronchi in a tuberculous area may be obstructed by caseous masses, coagulation of blood, granulations, and secretions, which repeatedly cause atelectasis. These findings, as well as the stripe-form atelectasis of Fleischner, have been confirmed by dissection. But all this cannot be brought about, except by the elimination of collateral ventilation.

It is possible that this elimination of collateral ventilation is also connected with the *selective collapse of the lung*. It would take us too far afield to deal with the whole question of atelectasis. We will mention only the fact that French and Italian authors such as Cardis,[9] Chadourne,[10] and Parodi[11] have drawn attention to the so-called *reflective collapse of the lung*. Through the action of the pulmonary musculature, which has been the object of much controversy recently, a lobe or a whole lung is supposed to collapse. This explains syndromes such as postoperative and traumatic collapse of the lung. Selective collapse of the lung is observed particularly in the case of a pneumothorax induced in the treatment of pulmonary tuberculosis. In these cases, the affected parts of the lung often collapse to a greater extent than the nonaffected ones. Good illustrations of this phenomenon may be found in a report by Bronkhorst and Dijkstra.[12] It is explained by different tonic conditions in the diseased parts of the lung. It may also be imagined, however, that certain side branches in the affected part of the lung are obstructed. The pneumothorax reduces the ventilation in that lung, the collateral ventilation is eliminated, and an atelectasis develops. In any case the mechanism of obstructing one or more side branches and eliminating collateral ventilation must be taken into account in explaining the phenomenon of atelectasis.

RECAPITULATION

After collateral ventilation had been established in dogs (van Allen and collaborators) and rabbits (Baarsma and Dirken), it now has been proved to exist in man as well. An entirely harmless method of recording the phenomenon in man is described. When the bronchus for a lobe is obstructed there is no collateral ventilation, and atelectasis follows. When a side branch is obstructed, there is no atelectasis, due to collateral ventilation. Atelectasis develops only if there is no collateral ventilation due to certain anatomic conditions, or if it is eliminated as a result of an inflammation or shallow breathing. The great importance of collateral ventilation for the clinic is further described.

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STUDIES ON EXPERIMENTAL PHOSGENE POISONING

II. PULMONARY ARTERY PRESSURE IN PHOSGENE-POISONED CATS

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IN SPITE of extensive study following the use of phosgene in chemical warfare, the mechanism by which this agent produces pulmonary edema is still obscure. Two general theories have been proposed: According to one, the edema is attributed to direct (toxic) injury to the endothelium of the pulmonary capillaries, while according to the other, the hydrostatic pressure within these vessels is believed to rise to levels sufficient to overbalance the colloidal osmotic pressure of the plasma. A third possibility, obstruction to the lymphatic drainage from the lung, has not received serious consideration except for recognition that the lymphatics seem inadequate to drain away significant amounts of alveolar fluid.[1-4]

The more probable concept of toxic endothelial damage has not been conclusively established, because efforts to demonstrate histologic evidence of endothelial injury have failed. Consequently, the alternative explanation has persisted, although its supporting evidence is indirect and unsatisfactory. This evidence consists of the reputed association of "blue" or "plum-colored" cyanosis (implying venous congestion) with phosgene poisoning in man,[5] and the occurrence of multiple thromboses or other changes assumed to be obstructive, in the pulmonary vascular system.[6-8] A modification of this general concept is Rothlin's[9] suggestion that the edema is brought about by a reflexly mediated vascular response but, since the experimental evidence on which this proposal was based could not be confirmed,[10] it may be dismissed from further consideration.

Arguments against the elevated pressure hypothesis may be summarized as follows: (a) The edema fluid, histologically and by analysis, is nearly identical with the blood plasma;[4, 10, 11] it is not a protein-poor filtrate of plasma. (b) There is reason to be skeptical of statements that the "blue" cyanosis and venous distention are a consequence of phosgene poisoning.[12] So far as can be determined from the literature, "blue" cyanosis has been reported only in field casualties of World War I, and in neither accidental phosgene poisonings[13-19] nor in experimentally poisoned animals.[8, 11, 20-22] It is clear from the literature of 1915 that chlorine does cause "blue" cyanosis and the subsequent use of mixtures of gases[5, 6, 14, 20] encourages the view that the "blue" cyanosis

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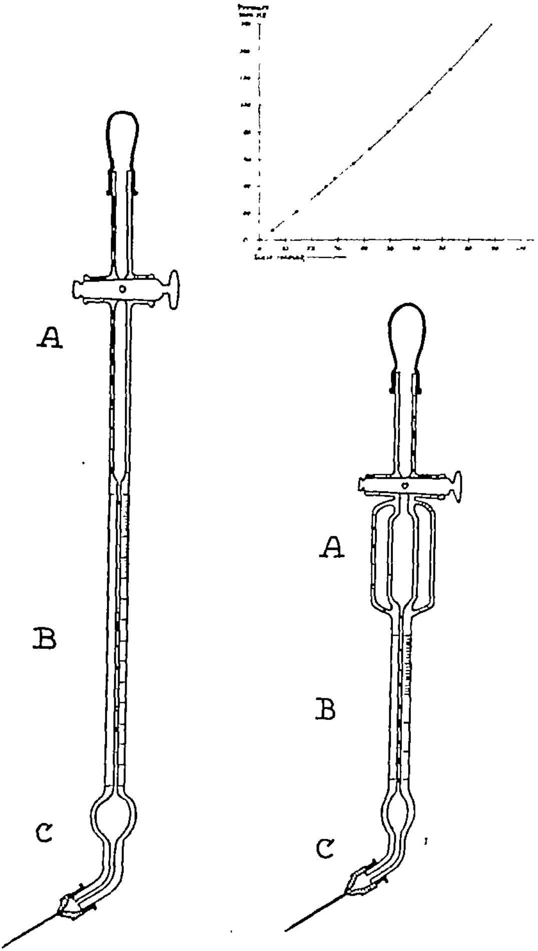

Fig. 1.—Line drawing of manometers used for measuring systemic (left) and pulmonary artery (right) blood pressures. The insert is a calibration curve for the systemic manometer.

of reputed phosgene casualties really was observed in mixed gas poisoning. (c) As reported elsewhere,[10] thromboses are exceptional in animals dying spontaneously within forty-eight hours after exposure to median concentrations of pure phosgene; the earlier reports of thrombosis seem not to have been interpreted with regard to the probable conditions of exposure. (d) Dogs and rats which were thoroughly heparinized before and continuously after exposure to phosgene have developed typical edema.[21] (e) Measurements of right ventricular pressure in phosgene-poisoned goats and dogs[22, 23] lead to the inference that pulmonary artery pressures are not abnormal. (f) Daly and associates[24] have observed no appreciable rises in pulmonary artery pressures in perfused dog lungs until nonspecific edema was present in both the gased and the control lung; their evidence suggests vasodilatation and pooling in the isolated gassed lung.

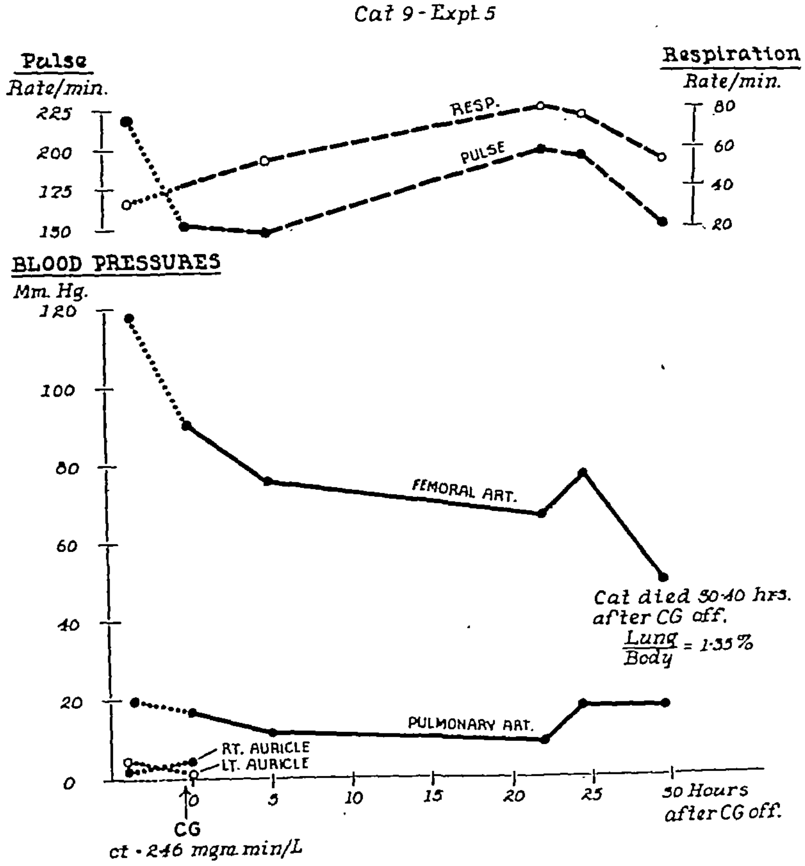

Fig. 2.—Phosgene poisoned cat.

These considerations, however, do not eliminate the possibility of elevated pulmonary vascular pressures as a factor in the pulmonary edema produced by phosgene. In view of its basic importance, the problem was attacked by direct measurement of the pulmonary artery pressure and by evaluation of the pulmonary pressure gradient.

METHODS

Cats were used in this study, because their thoracic structure lends itself best to a marsupialized heart preparation which permits access to the heart and great vessels in the unanesthetized animal.[23] At a preliminary operation, the left fourth and fifth costal cartilages with bits of the adjacent ribs were resected, the pericardium sutured securely to the margins of the defect, and the wound closed. After complete recovery in three to five weeks, the skin and pericardium covering the opening were incised under very light anesthesia (Pentothal Sodium or Evipal) a few hours before gassing; the femoral artery also was exposed. Normal cats were similarly anesthetized and the femoral arteries isolated; these animals served also as gas chamber controls.

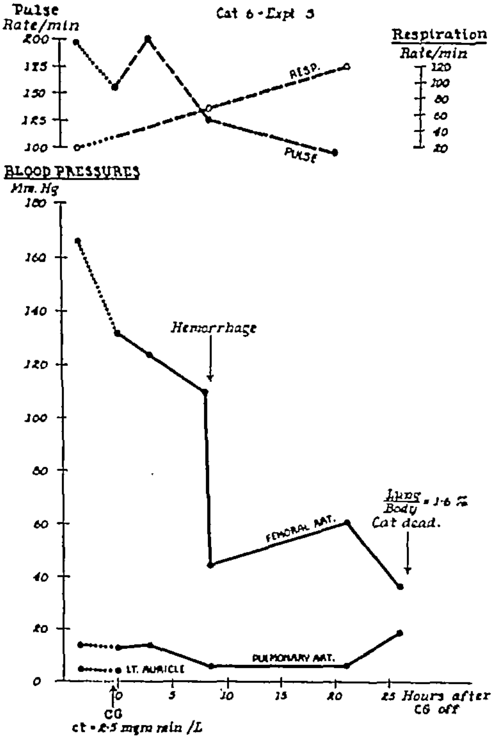

Fig 3.—Phosgene poisoned cat.

The prepared animals, each paired with a control, were exposed to varying doses of phosgene in a dynamic chamber by the standard "push-pull" technique described elsewhere.[10] The concentration-time (CT) products of exposure, in milligram-minutes per liter, were selected to produce varying degrees of severity of poisoning and edema; the mean concentration (C) was 0.29 mg. per liter ± 7 per cent; the duration of exposure (T) being varied from 8½ to 13 minutes.

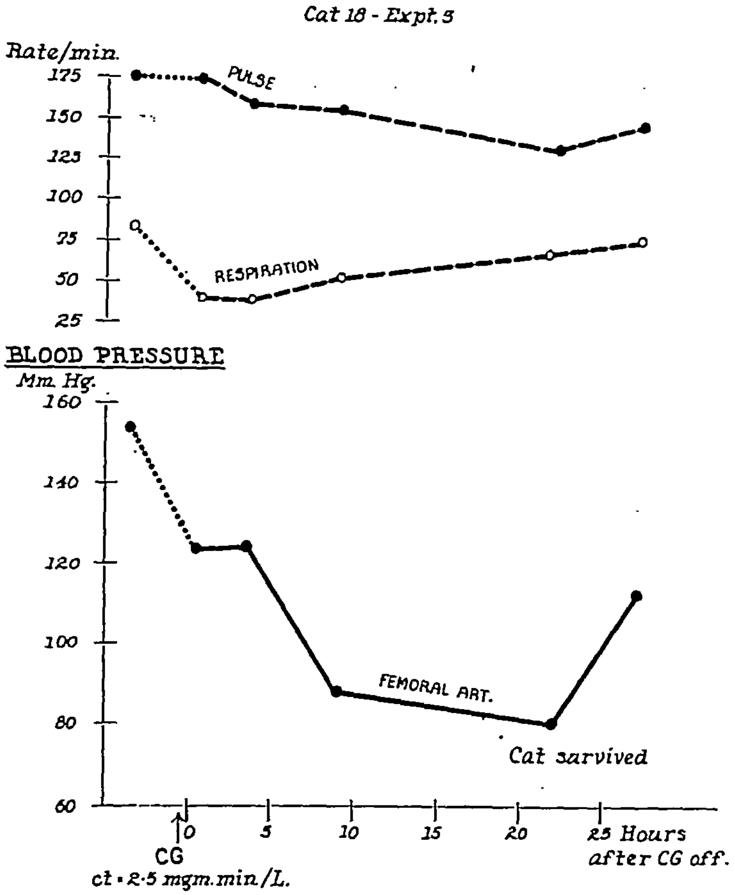

Fig. 4.—Phosgene poisoned cat (a simultaneously gassed control).

At death or sacrifice, complete autopsies were performed and the organs studied histologically. In the animals living longer than twenty-four hours, a fibrinopurulent pericarditis developed which was only partially controlled by sulfonamides.

At intervals after gassing, the animals were restrained in the supine position and the pressures were measured by means of manometers designed and built by R. D. Boche (Fig. 1). In operation, isotonic citrate is drawn into the bulb (C) to the zero mark on the calibrated stem (B); with the manometer vertical the stopcock is then closed, and the needle inserted into the vessel, taking care to keep the manometer vertical and to avoid warming the air-containing portion (A). Theoretical and experimental calibrations of the stem agreed almost perfectly. The recorded values represent mean pressures due to the damping characteristics of the instruments. Since the needle on the manometer was directed centrally in the vessels, the recorded pressures are the sum of the velocity and static pressure heads.

Because each reading necessitated puncture of the vessel or heart wall, the number of readings was kept to the minimum necessary for the required information. Between readings the cats were unrestrained.

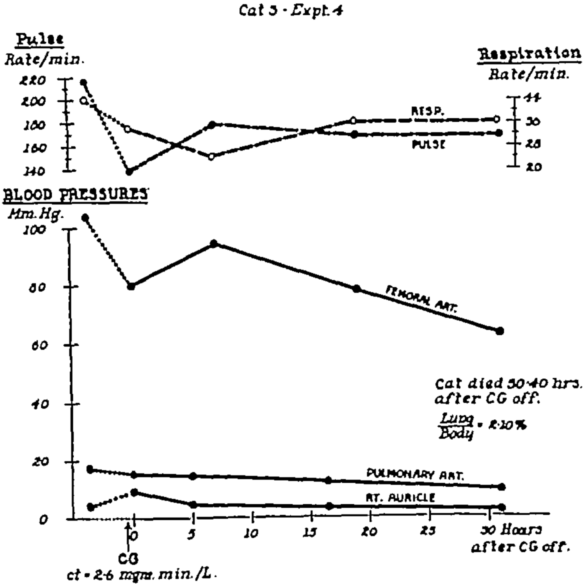

Fig. 3.—Phosgene poisoned cat.

RESULTS

The data on five prepared cats and on two of the five simultaneous controls are presented in graphic form in Figs. 2 to 8 (Figs. 4 and 8 are control animals) in order of increasingly severe exposure to phosgene (CG). The signs and course of poisoning in the prepared animals were in all respects similar to those in the controls. The inadvertent hemorrhage noted in Fig. 3 consists of a 10 to 15 c.c. loss from the femoral artery.

It is evident that the pulmonary artery pressures rarely rose above the pregassing values except terminally; the tendency was toward a fall, synchronous with the systemic pressures. With one exception, the animals showed the typical bradycardia at once after exposure, but thereafter the pulse and respiratory rates varied widely, attributable in part to the degree of acquiescence by the animal to the supine position. The majority of the readings were taken after the animal had relaxed, but in a few instances the value noted is that obtained between bouts of struggling or meowing. Such values may be somewhat higher than those which would have been obtained otherwise. The supine position seemed especially objectionable to the cats after edema had begun to develop.

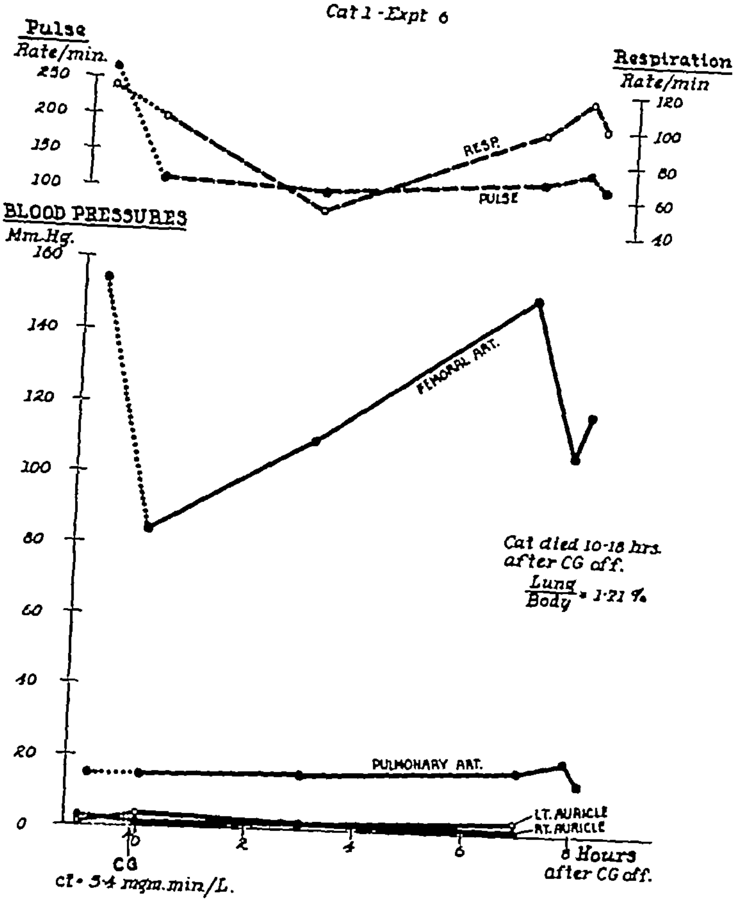

Fig. 6.—Phosgene poisoned cat.

Although few in number, measurements of pressure in the right and left auricles indicate that no essential changes were present after gassing.

Judged both by gross and histologic examination and by increase of the lung/body weight ratio, these cats showed a lesser degree of pulmonary edema in proportion to their clinical condition than was usually found in dogs. Hemoconcentration also was less pronounced in cats during the course of poisoning and at death.

DISCUSSION

The pulmonary artery pressures before exposure to phosgene lie within the range of pressures observed in similarly prepared cats using a different type of manometer,[26] and recorded values for mean pulmonary artery pressure in cats and in other species by various techniques are comparable with those recorded here.[27-29] While exposure of the intrapericardial structures to atmospheric pressure undoubtedly results in the development of abnormal pressure relations,[30] the validity of these data is not affected by these experimental conditions, since (a) the pulmonary artery pressures before gassing were normal, and (b) they fell after gassing instead of rising, as would have occurred if the preparation had predisposed *per se* toward appreciable accumulation of blood in the lungs. Furthermore, the chief interest centers on the relative pressures before and after gassing. The slight terminal rises of pressure in Figs. 2, 3, 6, and 7 may be due in part to the accentuated expiratory efforts characteristic of advanced phosgene poisoning.[11]

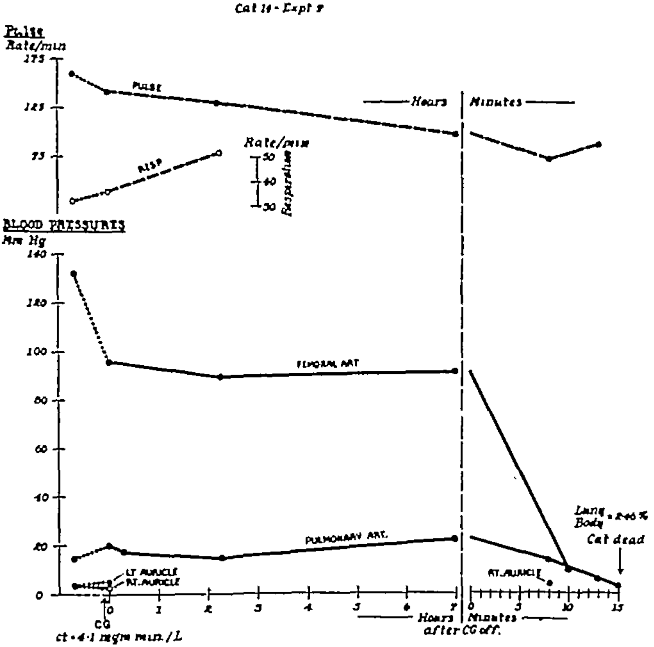

Fig. 7.—Phosgene poisoned cat.

The observations of left auricular pressure, although unavoidably incomplete, support the assumption that the pressure gradient across the lung follows the usual slope. There is no anatomic evidence to suggest that the major pressure loss occurs distal to the pulmonary capillaries. There seems to have occurred an effective adjustment by the lesser circulation toward maintenance of nearly normal pressure levels and gradient, in the presence of extensive disturbances of systemic pressure, heart rate, blood volume and viscosity, and the development of severe or lethal edema.

These data, together with the evidence outlined in the introduction, make untenable the hypothesis that the pulmonary edema of phosgene poisoning is of purely hydrostatic origin. This statement is further strengthened by the fact that the preparation employed should have exaggerated the hydrostatic factors leading to edema. It is obvious, however, that maintenance of any pressure sufficient to sustain circulation contributes to continued outflow of fluid into the alveoli, whatever the primary mechanism initiating the edema.

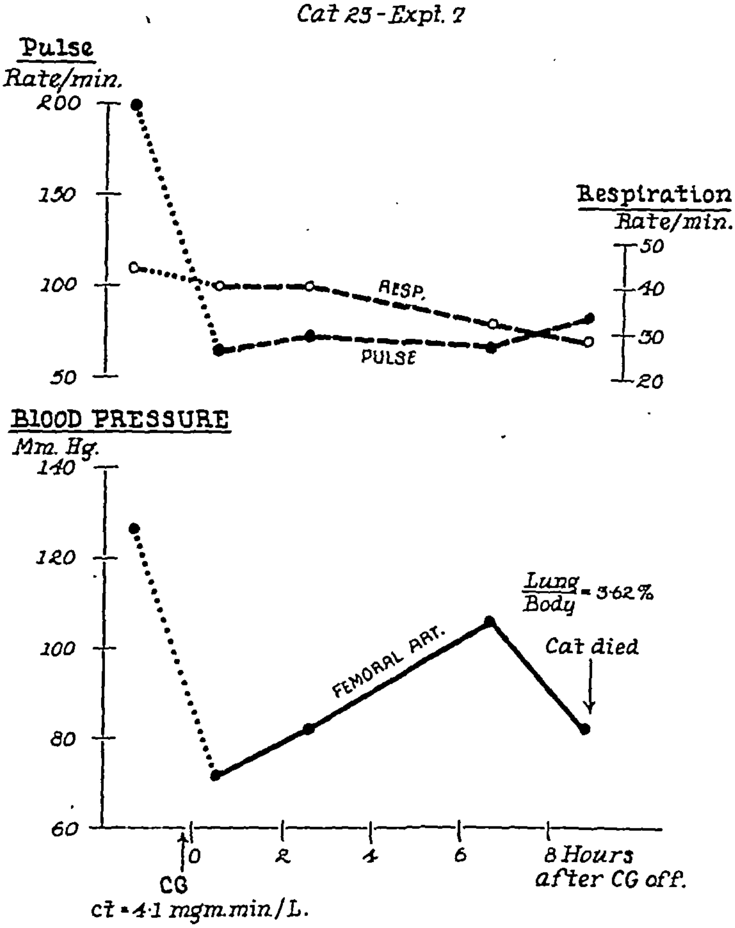

Fig. 8.—Phosgene poisoned cat (a simultaneously gassed control).

Since there appear to be no reasons for assuming that the cat's anatomic and physiologic response to phosgene is peculiar to that species in any fundamental respect, these data lead to the following suggestions regarding the therapy of phosgene poisoning in man: (1) There appears to be no indication for venesection, which previously has been carried out for the purpose of reducing pulmonary and systemic venous congestion. (2) Drugs tending to increase pulmonary artery pressure, e.g., Adrenalin,[27] should not be given. (3) Because the observed hemodynamics may represent an effective body adjustment to phosgene damage, it may be unwise to interfere by means of drugs or procedures intended to support or depress a particular sector of the circulation or heart. The most pressing defect is anoxic anoxia and attention should be concentrated upon relieving it.

SUMMARY

1. Pulmonary artery, and right and left auricular pressures have been measured directly in five cats poisoned with phosgene.

2. Abnormal elevations of pressure were not found after gassing.

3. Collateral evidence is cited for dismissing the hypothesis of an hydrostatic origin of pulmonary edema in phosgene poisoning.

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THE LOCALIZATION OF PULMONARY CAVITIES BY A MODIFIED ROENTGENOGRAPHIC TECHNIQUE

JOSEPH GORDON, M.D.*
RAY BROOK, N. Y.

THE size and location of a tuberculous pulmonary cavity determines the extent of a thoracoplasty. The conventional posteroanterior roentgenogram ordinarily used is not always satisfactory for accurate localization of the cavity with relation to the overlying ribs. A more reliable method for determining its position will be described.

The technique for roentgen ray examination of the chest is not standardized. In communications from several members† of the Committee on X-Ray Apparatus and Technique of the American Trudeau Society, the tube position mentioned varied from the fourth vertebral space, sixth vertebral space to 6 inches from the top of the casette. However, practically everyone uses the posteroanterior projection. Since the primary purpose of the routine x-ray examination of the chest is the detection of abnormal shadows and not accurate localization, this technique is generally satisfactory. For more accurate study the central ray of the tube should pass through the object being examined and the projection should be such that the object is adjacent to the casette.

In the majority of instances antra are situated in the upper and posterior part of the lung. In this situation the anteroposterior projection is to be preferred for accuracy rather than the routine posteroanterior projection. Distortion is further diminished and accurate localization enhanced by placing the x-ray tube on the same level as the cavity, that is, centering the tube on the cavity. Both projection and centering are determined by means of fluoroscopic examination and then x-ray films are obtained. The discrepancies due to changing the tube position and projection were demonstrated by the following procedures:

An object simulating a cavity was placed within the thorax of a skeleton, its position fixed and noted. Fluoroscopic examination was then carried out and the varying location of the image on the screen observed. For example, with the cavity known to be at the level of the fourth rib posteriorly, the annular shadow appeared to be at the level of the fifth rib when the tube was placed at midthoracic level using the posteroanterior projection. The tube and screen were then centered on the cavity by reducing the screen aperture so as just to encompass the annular shadow. Here the shadow appeared at the level of the fourth rib. In the anteroposterior projection, with the tube at mid-thorax, the annular shadow appeared to be slightly above the fourth rib or somewhat higher than its known position. When the tube was "centered," so that the central ray

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†Personal communications.

passed through the cavity, the correct location was visualized. The difference here was that in the anteroposterior projection the object was nearer the screen and magnification of the cavity was less in contrast to the posteroanterior projection. For a cavity near the anterior chest wall, distortion in size was, of course, less in the posteroanterior projection. Films taken of the skeleton with the x-ray tube in positions similar to that of fluoroscopy showed the same variations in location of the annular shadow. (Fig. 1.)

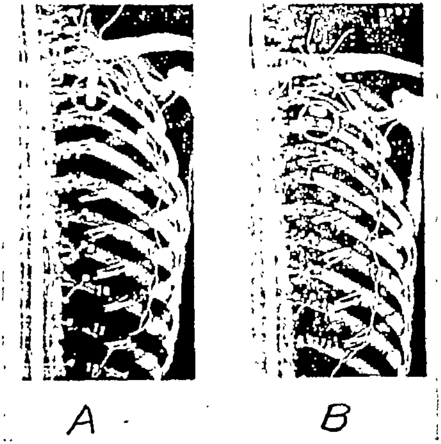

Fig. 1.—*A*, Posteroanterior roentgenogram of skeleton with simulated cavity located posteriorly and seen at fifth rib.

B, Anteroposterior spot roentgenogram showing cavity located in fourth interspace and known to be in this location.

By means of fluoroscopy and roentgenography, studies were made of patients with intrapulmonary cavities. The fluoroscopic findings corresponded with those noted above when using the skeleton. A series of films were then taken, conventional posteroanterior and anteroposterior, stereoscopic pairs, laterals, fluoroscopic spot films in both posteroanterior and anteroposterior projection, and "special spot" films, posteroanterior and anteroposterior. The fluoroscopic spot films were taken with the tube and screen centered as described above, the shutter being opened full for x-raying after fixing the position of the tube. The "special spot" films were obtained in the following manner: The annular shadow, localized by the same fluoroscopic method, was outlined on the skin both in front and back. The patient was then taken to the x-ray room and placed before the casette and the tube stand moved up to align the center of the x-ray tube with the skin mark. With the tube anchored at this level, the tube stand was moved back to a distance of 72 inches and films were taken in both anteroposterior and posteroanterior projections. Lateral films were taken at the same level at the recommended 48-inch distance.

The group of films taken on the same patient were then compared and from fluoroscopic studies and lateral films, the position of the cavity in relation to the anterior or posterior chest wall was shown. The cavity which lay nearer the posterior chest wall appeared lower in the conventional posteroanterior film and somewhat higher in the anteroposterior film than the level determined by fluoroscopy. In the films taken with the tube aligned to the skin markings ("special spot" technique), the location of the annular shadow in the anteroposterior pro-

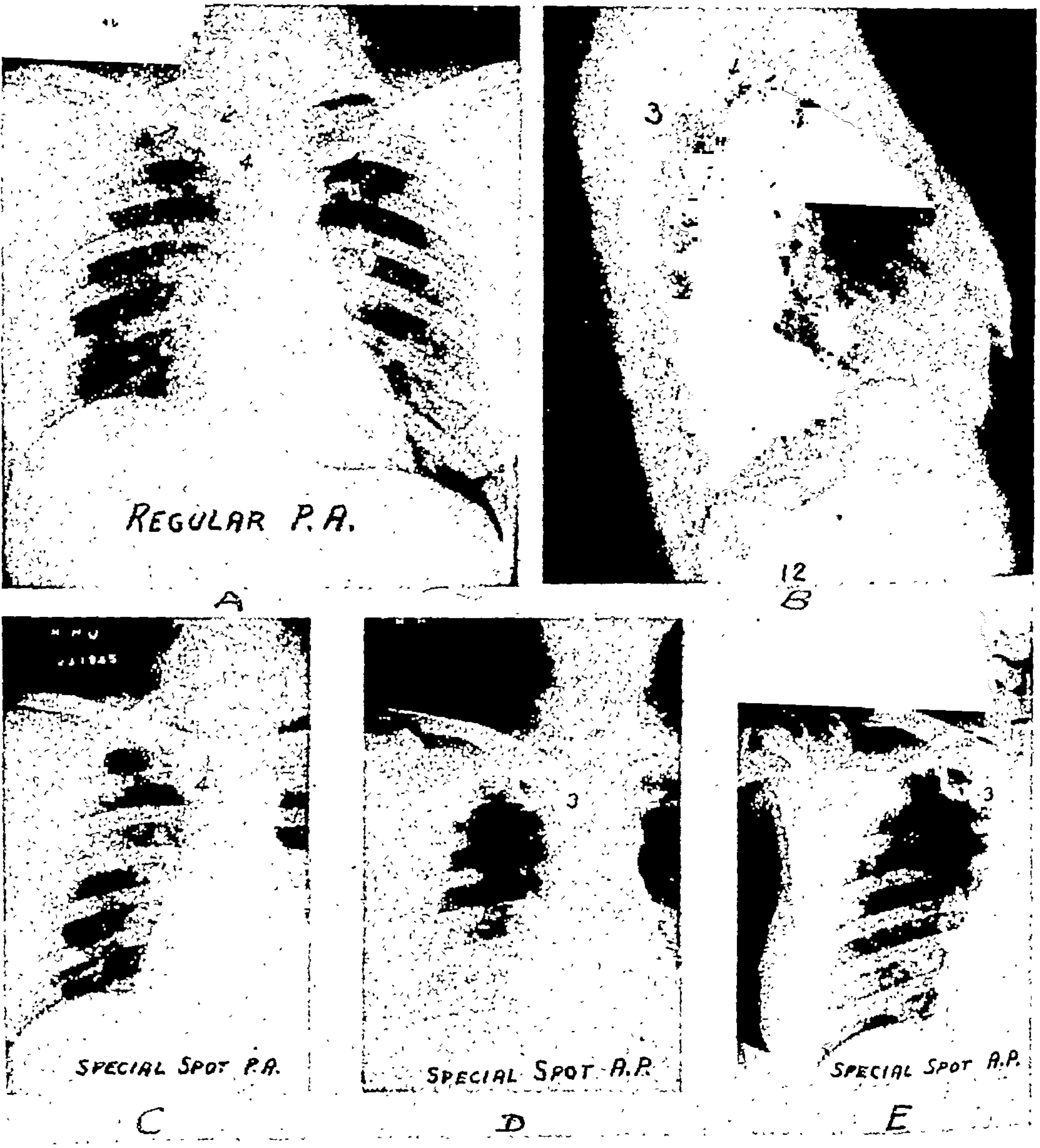

Fig. 2.—*A*, Conventional posteroanterior film showing annular shadow at level of fourth rib.

B, Right lateral film showing annular shadow at level of third rib and located well posteriorly.

C, Film taken with tube located at level of cavity but still using posteroanterior projection. Annular shadow moved upward to third interspace above fourth rib.

D, Film taken as in *C*, but projection is anteroposterior for posterior cavity, which is now seen at third rib.

E, Film taken as in *D*, but with Bucky technique for sharper detail.

jection corresponded with the fluoroscopic centering and the posteroanterior showed only slight changes, chiefly those of magnification. The fluoroscopic spot films were similar to the special technique but magnification and distortion were present because of the short tube distance. The most striking difference was noted in comparing the conventional posteroanterior film with the "special spot" anteroposterior film. (Figs. 2 and 3.) The stereoscopic films were inaccurate because the fusion image was that of two different positions, low tube and high tube without regard to the location of the lesion.

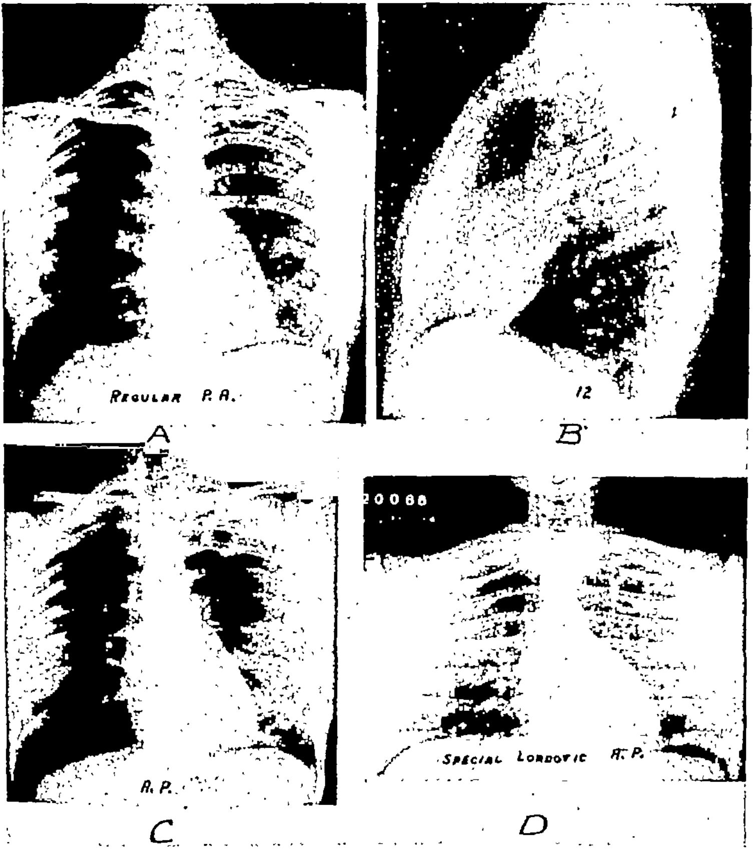

Fig. 3.—A, conventional film showing annular shadow at level of fifth rib.

B, Left lateral film showing annular shadow at level of fourth rib and located posteriorly.

C, Film taken at level of cavity and correct or anteroposterior projection showing annular shadow at level of fourth rib.

D, Lordotic film taken in anteroposterior projection showing annular shadow above the plane of the fourth rib.

When the cavity lies virtually midway between the anterior and posterior chest walls, there is no significant difference in rib location in either the anteroposterior or posteroanterior spot films. Also, when the transverse diameter of the chest is increased because of kyphosis and the cavity thereby apparently lies about at the middle of this distance—no change in anteroposterior or posteroanterior spot is noted. When the cavity is in intimate proximity with the pos-

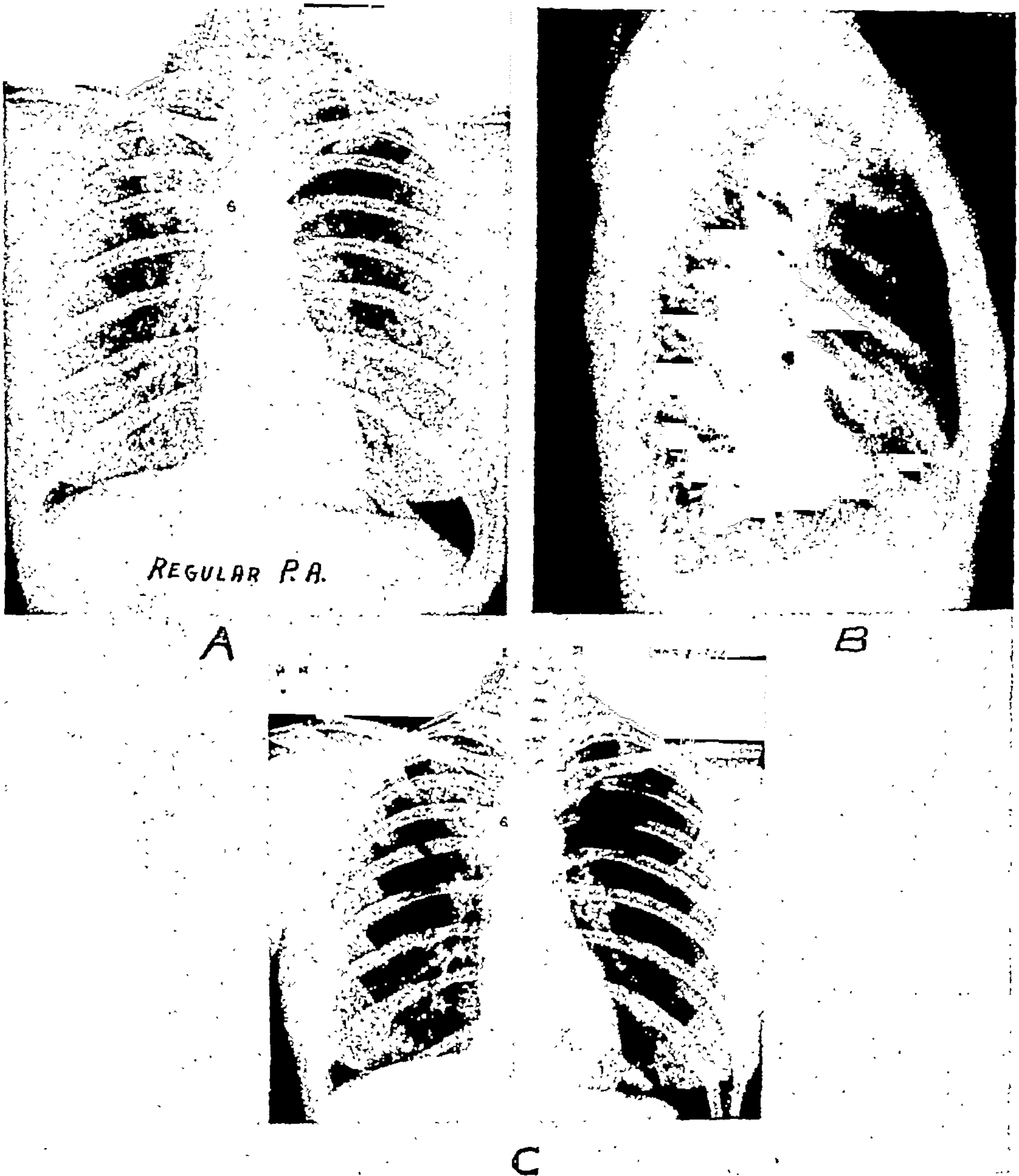

Fig. 4.—A, Regular film showing annular shadow at level of sixth rib.

B, Right lateral annular shadow at level of third rib but located well anteriorly.

C, Special spot film taken with tube at level of cavity and in posteroanterior projection because of anterior location of cavity. No essential difference is noted as the posteroanterior projection is correct for such a cavity and the sixth rib is midthoracic for tube location.

terior ribs, a regular anteroposterior film compared with a spot anteroposterior film shows insignificant change in location. The same is also true for a cavity in close proximity to the anterior chest wall when the films are taken in the posteroanterior projection. (Fig. 4.)

It would seem, therefore, that the relationship of a tuberculous pulmonary cavity to the overlying ribs is best determined by the technique indicated above. The proper projection is first determined by fluoroscopy or from a lateral film so that when films are taken, the position of the patient places the cavity the shorter distance from the casette. The alignment of the tube with the skin mark assures that the central ray passes through the object to be examined. The correction is in both the vertical and horizontal planes, thus considering the rib levels, the distance from the vertebral column, and the relationship to thoracic body lines.

In the technique of thoracoplasty operations it is generally advised that resection be carried one or two ribs below the cavity, assuming no significant lesions beneath it. On the basis of the above technique, it would be possible, in some cases, to resect fewer ribs and still be below the roentgen level of the cavity as contrasted with the shadow in the conventional film. Only a clinical trial, however, can determine the success attending the use of this type of roentgenogram as a guide to the extent of the operation.

Illustrations kindly prepared by Anna Sanlow, Senior X-ray Technician, Ray Brook, N. Y.

THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

Twenty-Eighth Annual Meeting

May 31, June 1 and 2, 1948, Chateau Frontenac
Quebec

Preliminary Program

Monday Morning, May 31, 1948

9:00 A.M. BUSINESS MEETING

9:30 A.M. SCIENTIFIC SESSION

1. **Streptomycin as an Adjunct in Surgical Treatment of Pulmonary Tuberculosis**
   Daniel A. Mulvihill, Laurence Miscall and (by invitation) Robert Klopstock, Joseph Bitsack
2. **Role of Streptomycin in Surgery of Pulmonary Tuberculosis**
   P. T. Chapman (by invitation), E. J. O'Brien, Paul V. O'Rourke, and (by invitation) Bruce Douglas
3. **Experimental and Clinical Studies of the Role of Streptomycin in the Pleural Cavity**
   Edward J. Beattie (by invitation), Brian Blades, and (by invitation) Charles Horton
4. **Results in Pulmonary Resection for Tuberculosis (100 Cases Without Streptomycin Contrasted With 100 Cases Operated With Streptomycin Therapy)**
   Charles P. Bailey, and (by invitation) Thomas O'Neill, and Robert P. Glover
5. **An Evaluation of Streptomycin as a Protective Agent in Pulmonary Resections for Tuberculosis**
   J. A. Moore, J. D. Murphy, and (by invitation) P. D. Elrod
6. **An Anatomic Approach to Segmental Resection**
   J. Gordon Scannell (by invitation)
   Introduced by Edward D. Churchill

Monday Afternoon, May 31, 1948

2:00 P.M. SCIENTIFIC SESSION

7. **Endobronchial Occlusion During Pulmonary Resection**
   James D. Moody
8. **Medullary Pegging of Ribs in Thoracotomy Incisions**
   Karl P. Klassen
9. **Sputum in Cancer of the Lung: A Study of the Incidence and Causative Factors**
   John R. McDonald (by invitation), Stuart W. Harrington, and O. Theron Clagett
10. **Cytology of Bronchial Secretions—an Aid to Early Diagnosis of Lung Cancer**
    William L. Watson and (by invitation) Henry Cromwell, Lloyd Craver, and George N. Papanicolaou
11. **Malignant Nature of Bronchial Adenoma**
    Alfred Goldman
12. **Adenoma of the Bronchus**
    Harold Neuhof and (by invitation) Coleman B. Rabin

Tuesday Morning, June 1, 1948

9:00 A.M. SCIENTIFIC SESSION

13. **The Clinical Use of a Prosthesis to Prevent Overdistension of the Remaining Lung Following Pneumonectomy**
    Julian Johnson and (by invitation) Charles K. Kirby

14. **An Evaluation of Extrapleural Pneumonolysis With Lucite Plombage**
    Josiah C. Trent (by invitation), James D. Moody, and Joseph S. Hiatt, Jr.

15. **Experimental and Clinical Study of Collapse Therapy Using Fiberglas Wool Fabric**
    (By Invitation) Thomas J. O'Neill, Hector P. Redondo, and Robert G. Trout

16. **Intrathoracic Meningocele**
    Francis X. Byron and (by invitation) Emery E. Alling, and Paul C. Samson

17. **Use of Pedicle Tube Flap in Carcinoma of Upper Esophagus**
    Eugene Bricker (by invitation) and Thomas H. Burford

18. **Transthoracic Esophago-Jejunogastrostomy for High Stricture of the Esophagus**
    Albert Wilson Harrison

19. **Completing the Multiple-Stage Operation for Atresia of the Esophagus**
    Conrad R. Lam

Tuesday Afternoon, June 1, 1948

2:00 P.M. EXECUTIVE SESSION

3:00 P.M. SCIENTIFIC SESSION

Address of the President—Alton Ochsner. Factors Influencing Survival Rate in Primary Pulmonary Malignancy

20. **Decortication in Pulmonary Tuberculosis Including Studies of Respiratory Physiology**
    Joseph Gordon and Edward S. Welles

21. **Decortication of the Unexpanded Tuberculous Lung Following Pneumothorax**
    Joseph A. Weinberg and (by invitation) J. Dwight Davis

22. **Physiological Observations Concerning Decortication of the Lung**
    George W. Wright, Lester B. Yee, Giles F. Filley, and Allan Strannahan (by invitation)

23. **Allergy of Tuberculosis, With Special Reference to Autotuberculinization**
    A. R. Judd

Wednesday Morning, June 2, 1948

9:00 A.M. SCIENTIFIC SESSION

24. **Chronic Atelectasis and Pneumonitis of the Middle Lobe**
    Donald L. Paulson and Robert R. Shaw

25. **Surgical Management of Pulmonary Coccidioidomycosis in Focalized Lesions**
    Sam J. Greer (by invitation), James H. Forsee, and (by invitation) Hugh W. Mahon

26. **Changes in Blood Volume and Available Fluid Volume During Thoracic Operations**
    Bernard J. Miller (by invitation), John H. Gibbon, Jr., and Frank F. Allbritten, Jr.

27. **Monaldi Suction in the Treatment of Bullous Emphysema and Large Pulmonary Cysts**
    Jerome R. Head and (by invitation) Edward E. Avery

28. **A Review of Seven Years' Experience With Intracavitary (Monaldi) Drainage of Tuberculous Cavities**
    Warriner Woodruff, Winfield O. Kelley, and (by invitation) Allan Strannahan

Wednesday Afternoon, June 2, 1948

2:00 P.M. SCIENTIFIC SESSION

29. **Coarctation of the Aorta**
    H. Brodie Stephens and (by invitation) Orville F. Grimes
30. **The Correction of Aortic Insufficiency in Dogs With an Artificial Aortic Valve**
    J. Moore Campbell (by invitation)
31. **Experiences With the Anastomosis of the Left Subclavian Artery to Left Pulmonary Artery for Pulmonary Stenosis**
    Emile Holman
32. **Development of Anastomosis Between Coronary Vessels and Transplanted Internal Mammary Artery**
    Arthur M. Vineberg
33. **An Experimental Study in Bronchial Anastomosis.**
    Truxton Jackson, Phillip Lefkin (by invitation), William M. Tuttle, and (by invitation) Foster Hampton
34. **Mesothelial Mediastinal Cysts**
    Everett C. Drash

In addition to the papers listed here, two others have been submitted for the Rose Lampert Graff prize as follows:

Decortication of Nonexpandible Postpneumothorax Tuberculous Lung
Daniel A. Mulvihill and (by invitation) Robert Klopstock

Bilobectomy: Surgical and Anatomical Considerations in Resection of Right Middle and Lower Lobes Through the Intermediate Bronchus
Gustaf E. Lindskog and (by invitation) Liebow and Hales

Papers to Be Read by Title

1. **The Use of Streptomycin in the Preparation and Protection of Patients With Pulmonary Tuberculosis Treated by Extrapleural Thoracoplasty**
   James H. Forsee, and (by invitation) A. J. Neerken and Carl W. Tempel
2. **Phrenic Nerve Paralysis—Special Consideration of the Accessory Phrenic Nerve**
   Winfield O. Kelley
3. **Experiences With the Surgical Resection of the Human Carina, Tracheal Wall and Contralateral Bronchial Wall, in Cases of Right Total Pneumonectomy**
   Osler A. Abbott
4. **An Exact Method of Delineation of Bronchial Pulmonary Segments During Pulmonary Resection by Endobronchial Injection of Dyes**
   Charles P. Bailey
5. **Diaphragmatic Hernia**
   Herbert Willy Meyer
6. **Evaluation of Plombage in the Treatment of Chronic Pulmonary Disease**
   H. Ryerson Decker
7. **Emergency Management of Massive Pulmonary Hemorrhage**
   Alfred Goldman
8. **The Present Status of Bronchoscopy in Relation to Thoracic Surgery**
   Chevalier L. Jackson
9. **Lipoid Pneumonia Resulting From a Dermoid Cyst**
   A. Lincoln Brown
10. **Endobronchial Balloon for the Control of Bronchial Secretions During Lobectomy and Pneumonectomy**
    James D. Moody and George W. Newton (by invitation)
11. **Acute Putrid Pulmonary Abscess—the Later Results of Operative Treatment**
    Arthur S. W. Touroff and (by invitation) Robert A. Nabatoff, and Harold Neuhof
12. **Total Pleurectomy and Pneumonectomy for Cavitary Pulmonary Tuberculosis Complicated by Tuberculous Empyema**
    Daniel A. Mulvihill and (by invitation) Ralph Friedlander
13. **A Discussion of a Series of Operations for Coarctation of the Aorta and the Problems Involved**
    John C. Jones
14. **Transthoracic, Thoracoabdominal Portacaval Anastomosis**
    Victor P. Satinsky, H. P. Redondo Ramirez, and Lawrence Gilbert (by invitation)
15. **Intercostal Approach in Transpleural Operations**
    Joseph A. Weinberg and (by invitation) Alvin R. Kraus

The Journal of Thoracic Surgery

VOL. 17 JUNE, 1948 NO. 3

Original Communications

AUGMENTED AND CONTROLLED BREATHING IN TRANSPLEURAL OPERATIONS

FREDERICK R. MAUTZ, M.D., CLAUDE S. BECK, M.D., AND
(BY INVITATION) HAROLD F. CHASE, M.D.
CLEVELAND, OHIO

INTRODUCTION

NO DOUBT the two decades just passed will be remembered as the period of most rapid expansion and development in the surgical approach to the treatment of intrathoracic lesions. This development came considerably later than corresponding technical developments in the surgery of other regions of the body. If we were to speculate why this was so, we would almost certainly conclude that it was because the earlier thoracic surgeons found it necessary first to become practical physiologists in order to understand and attempt to prevent the disturbances of respiration associated with pneumothorax before direct operative intervention could be contemplated upon intrathoracic lesions.

It seems certain that there was an undue fear of open pneumothorax in man and this was probably due to the experiences with open pneumothorax in the laboratory. A unilateral pneumothorax in at least some of the common laboratory animals is the equivalent of a bilateral pneumothorax in man. In the dog, for example, the mediastinal membrane is exceedingly thin and flimsy and there is a large open communication between the two pleural cavities. Even today it is not always easy to translate our experiences from the laboratory to the clinic, even though the fundamental physiologic principles remain the same. But if our laboratory experiences cause us to approach the contents of the thorax in man with undue caution, it is not difficult to contemplate the retardation thoracic surgery would have suffered without the laboratory as a proving ground. As we follow the early developments in thoracic surgery we see the pioneers become infected with ideas as a result of their contact with both the clinic and the laboratory. As to the problem of open pneumothorax, we can clearly trace the

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From University Hospitals of Cleveland and the Surgical Laboratory of Western Reserve School of Medicine.

Read before the Twenty-seventh Annual Meeting of the American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

infection of ideas through such surgeons as Brauer, Von Mikulicz, Sauerbruch, Willy Meyer, Graham, and Crafoord, to mention only a few. As a result, we find that today transpleural operations are as safe as laparotomies.

This does not mean that all the physiologic problems of open pneumothorax are solved and that everyone is in full agreement.[1-3] On the contrary, there are probably few subjects on which so many controversial opinions have been expressed in recent years. It is the purpose of this paper to discuss our physiologic concepts of the most fundamental phenomena of open pneumothorax and also to discuss our own approach to the problem of integrating control of physiologic disturbances of pneumothorax with anesthesia.

FACTORS AFFECTING PULMONARY VENTILATION IN OPEN PNEUMOTHORAX

In the unanesthetized, intact individual, the level of pulmonary ventilation is determined principally by the metabolic rate, due to the extreme sensitivity of the respiratory center to the increase or decrease of CO_2 tension.[4] For example, a lowering of alveolar CO_2 from 5.6 per cent to 5.0 per cent by voluntary hyperventilation will produce apnea. This form of apnea is not respiratory failure since the respiratory center is very much alive, providing extreme and prolonged hypocapnea is avoided, and when the CO_2 tension returns to a normal level, respirations are resumed. On the other hand an increase of the CO_2 content of the inspired air decreases the pressure gradient for CO_2 outflow from the body. A 3 per cent concentration of CO_2 in the inspired air will cause doubling of the minute volume of respiration while a 6 per cent concentration of CO_2 in the inspired air will cause an eightfold increase in minute volume.

The alveolar CO_2 is in this way maintained fairly constant by *increased minute volume of exchange to compensate for diminished pressure gradient* until the content of the inspired air nearly equals the normal alveolar concentration. This compensation depends upon the action of an alert respiratory center and adequate motor respiratory mechanisms.

One of the objectives during transpleural operations should be to maintain pulmonary ventilation that will exactly take care of the metabolic needs of the body. It has been shown by a number of investigators[5-7] during the past forty years that under conditions of anesthesia, with beginning pulmonary insufficiency there is greater interference with CO_2 elimination than with O_2 entrance. Many premedicant drugs and anesthetic agents reduce the sensitivity of the respiratory center to CO_2. Morphine, barbiturates, and cyclopropane are almost specific in this regard. Light ether anesthesia stimulates respiration, but deep ether anesthesia depresses the sensitivity of the respiratory center to CO_2. For this reason, *the response of the respiratory mechanism to CO_2 accumulation is not as great as in the normal unanesthetized individual.* In practice, it has been possible to compensate for hypoxia by increase in the partial pressure of O_2 in the inspired mixture. If an increased pressure gradient of O_2 between inspired and alveolar air is necessary to oxygenate the blood, it is obvious that, if respiratory volume remains constant or is limited in reserve, the pressure gradient of CO_2 must be *equally exaggerated in the opposite direction* by accumulation of CO_2 in the blood stream and alveoli to permit CO_2 to diffuse from the body. This condition of excessive CO_2 accumulation may exist because of the unresponsiveness of the respiratory center and the compromised respiratory motor mechanisms in the anesthetized patient with open pneumothorax.[8] In this state of beginning pulmonary insufficiency the normal warning signs of hyperpnea which normally indicate accumulating CO_2 do not appear. In some instances of deep anesthesia the principal factors responsible for maintenance of spontaneous breathing may be reflex stimulation due to wound trauma or to pulmonary, aortic, and carotid sinus reflexes. When these reflexes are withdrawn apnea may supervene, representing true respiratory failure.[9]

Mechanical factors that interfere with pulmonary ventilation are quite obvious but are not always easy to evaluate quantitatively.

Position on the operating table[10] will reduce vital capacity as much as 15 per cent even before the chest is opened. We do not know of any vital capacity measurements made on human subjects with open pneumothorax but it appears probable that the remaining vital capacity would be reduced by 50 per cent or more.

In the absence of breathing against positive pressure or obstruction, there is little pressure fluctuation in the trachea and bronchi during the respiratory cycle, a maximal gradient of 3 mm. mercury being sufficient to move the air in and out of the lungs. This pressure fluctuation is not sufficient to provide a significant volume change in the lung on the side of an open pneumothorax. When the patient is breathing into a taut breathing bag maintained at positive pressure by the constant addition of oxygen or other gases, there may be a considerable pressure variation during the respiratory cycle, depending upon the size and elasticity of the breathing bag. The pressure is *maximal* at the end of *expiration*, and *minimal* at the end of *inspiration*. It is obvious that the lung volume on the side of the pneumothorax will be determined by the intrabronchial pressure and that any fluctuation in the volume of that lung will always be opposite in direction to that of the intact lung. To our knowledge, no observations have been made of the volume of this pendulum air in patients under various breathing conditions but it would seem that in some instances there would be sufficient pendulum air to be physiologically significant. Under conditions of obstruction of the airway, the pendulum air exchange between the two lungs increases as the degree of obstruction becomes more severe, until the only transfer of air is between the two lungs.

There are compensatory mechanisms that prevent the development of CO_2 retention the moment a large open pneumothorax is made in man.[11, 12] Such compensation depends to some extent upon the large reserve breathing capacity in the normal intact individual. Under conditions that approximate a basal state, 10 per cent or less of the breathing capacity is utilized.

When a free pleural cavity is widely opened under local anesthesia or a light plane of ether anesthesia without any provisions for elevating intrabronchial pressure during any phase of the respiratory cycle, there is an *immediate* and *vigorous* increase in the respiratory effort. This is due to reflex stimulation of the respiratory center via the vagus nerve as a result of the sudden collapse of the lung on the side of the pneumothorax to approximately one-third of its original volume by virtue of its elastic recoil. The reflex stimulation of the respiratory center acts to compensate for any interference with pulmonary ventilation caused by the pneumothorax.

Other reflexes of importance are those from the wound which may either stimulate or inhibit respiratory effort and those from the larynx, trachea, and bronchi which either inhibit inspiration or stimulate powerful and prolonged expiration, the equivalent of a cough. The chemically originated reflexes from aortic and carotid sinus mechanisms are especially important when there is depression of the respiratory center to direct chemical stimulation in beginning pulmonary insufficiency.

Increased breathing effort in open pneumothorax will be reflected in a rise of the metabolic rate. The end result of all the changes in breathing in open pneumothorax will depend upon a quantitative summation of the individual factors contributing to and compensating for pulmonary insufficiency. But even though the pulmonary ventilation may keep up with the metabolic needs, *this is accomplished with reduction of reserve breathing capacity.* Ideally, it would be better at all times to have available the full physiologic reserves of the patient.

THE EVOLUTION OF AUGMENTED AND CONTROLLED PULMONARY VENTILATION

In 1555 Vesalius stated that "repeated inflations of the lungs" were necessary to maintain a vigorous heart action in the presence of bilateral pneumothorax in animals.[13] In physiologic laboratories, this method of pulmonary ventilation was universally adopted in thoracic exposures after the work of Volhard,[6] who, in 1908, described a simple mechanism for intermittent inflation of the lungs. He used this mechanism to maintain the respiration in curarized animals.

Thoracic surgeons, however, were thinking in terms of constant pressure differentials and were building pressure chambers. These soon gave way to the use of constant flow positive pressure with tracheal intubation and a closed carbon-dioxide absorption system. This was the status of an anesthesia for thoracic surgery ten years ago. Anyone working on thoracic problems in the laboratory and seeing the clinical thoracic surgery of that time must have wondered why clinical thoracic anesthesia could not be managed in much the same way as the laboratory anesthesia, since the latter was certainly better.

TECHNIQUE OF MECHANICALLY AUGMENTED AND CONTROLLED BREATHING

In 1940 a preliminary report was presented to this society[14] concerning our efforts of the previous three years to add mechanically produced intermittent pressure to anesthesia for clinical thoracic surgery. Reports of Crafoord's[7] work in Stockholm were received with great interest both as to basic physiologic needs for better pulmonary ventilation and as to the mechanical approach to the problem. Crafoord's spiropulsator seemed a bit too complicated. While we have developed a much simpler device, we believe there is still ample room for technical improvement. We have attempted to determine whether it should supplement or be a substitute for manual compression of the breathing bag, a practice that has become more frequent since the use of anesthetic agents such as cyclopropane, Pentothal, and curare which commonly produce varying degrees of failure of the respiratory mechanism.

We proceeded with caution in our initial application of this device to patients. At first we waited for instances of respiratory failure and had an opportunity to use our device in a considerable number of such cases simply as a pulmonary ventilator. These cases included a number of attempted resuscitations from ventricular fibrillation and cardiac standstill, and several patients with apnea from increased intracranial pressure due to head injuries and brain tumors. All except one of these patients eventually died from their original trouble. One patient with a brain tumor was operated upon in apnea and completely recovered after removal of a meningioma. One patient who had a medullary paralysis due to spinal anesthesia was carried for an hour in apnea and completely recovered. By this means we satisfied ourselves that, in the presence of apnea, adequate pulmonary ventilation could be provided in the patient with an intact thorax. This is a more severe test than in open pneumothorax since in addition to producing pulmonary expansion, the force of the positive pressure must move the chest wall, diaphragm, and abdominal contents in order to make room for lung expansion.

It has only been during the last three and one-half years that we have had ample opportunity to employ this device in an adequate number of transpleural operations so as to be able to answer some of the questions that arise regarding augmented and controlled breathing by mechanical means. We have used this method in only two general situations: (1) In open pneumothorax procedures, and (2) In patients with respiratory failure, as previously discussed.

Unless otherwise designated, the anesthetic agents have been nitrous oxide and ether until pneumothorax is produced, after which only ether and oxygen are added to the system unless there is gross leakage, in which case nitrous oxide may again be added. We may belong to a minority in adhering to ether for thoracic surgery but we believe that many complications which in the past have been attributed to ether irritation are now known to have been more likely due to such factors as chronic malnutrition and protein depletion, indiscreet use of intravenous fluids, and failure to take the necessary precautions to insure dry air passages during and after the operation, etc.

At first we were using intratracheal tubes only when there was likely to be blood or secretions in the air passages, including all pulmonary resections. More recently, we have been using such tubes in all patients (except infants and small children) and find the Magill tube with an inflatable cuff most advantageous. This prevents inflation of the stomach, which was objectionable in some of the earlier operations. The only complication observed due to the use of these tubes has been slight hoarseness.

No intrapulmonary pressure is allowed to build up before the pleural cavity is opened. When the pleura is opened, intermittent pressure is started at a rate of 12 to 16 per minute with peak pressures generally set for 15 mm. mercury.

In addition, a safety valve prevents pressures of over 20 mm. mercury from being applied. Frequently, a rate can be chosen about one-half that of the patient's respiratory rate so as to fit the mechanical breathing smoothly into the procedure. A little time must be taken by the surgeon to make certain that both lungs are responding to the intermittent pressure; occasional suctioning, adjusting the patient's position, tracheal tube, etc., are necessary before good bilateral expansion of the lungs is obtained.

Slight hyperventilation is carried out immediately after opening the pleura, with the soda-lime absorber in the circuit. This generally produces apnea in a few minutes, at least to the point that intercostal muscles cease to contract and diaphragmatic action is reduced to an ineffective level. Under such conditions it is possible frequently to test the state of the respiratory center by allowing CO_2 accumulation. An active center will show a rapid response by increased diaphragmatic activity. Diminution of respiratory effort when CO_2 is again absorbed is proof that the pulmonary ventilation is adequate.

Prior to the use of curare it had been necessary to increase the depth of anesthesia beyond that required for the surgical procedure in order to block stimuli which interfered with taking over control of breathing in some patients who were more difficult to control. We have not favored the production of central respiratory failure by drugs or anesthetic agents although this seems to have become a customary procedure in the hands of others.

Intocostrin or d-tubocararine is now used with increasing frequency in our thoracic patients to diminish the force of the patient's respiratory effort until the respirator has assumed control.[15] Usually, with patients under ether anesthesia, doses of 20 units repeated from two to five times during a three- to four-hour procedure suffice for the initial assumption and maintenance of control. Most of these patients have been carried in upper plane 2 of anesthesia, but with the increasing use of curare we are learning to carry the patients in a lighter plane of anesthesia. Deeper planes of general anesthesia are to be avoided due to the detrimental effect on the circulation.

We have been somewhat disappointed in the contribution of curare to the technique of intubation for, on two occasions following the use of this drug, the vocal cords were seen, on direct laryngoscopy, to be held in close apposition. In these instances the depth of anesthesia was increased after which intubation was performed without difficulty.

The most serious problem is concerned with gauging the depth of anesthesia, since mechanical breathing as well as other types of controlled respiration may be effective in overdosing the patient with anesthetic agent. Signs of eyeball motility and estimation of the degree of muscular relaxation by eyelid and jaw tonus are useful aids in this respect, but these may be much less reliable when curare is used. Occasional momentary cessation of artificial respiration and/or permitting accumulation of CO_2 as previously described with subsequent observation of the promptness with which the diaphragm is stimulated is a good index both of the depth of anesthesia and of status of the respiratory center. One particularly helpful approach to this problem of determination of depth of anesthesia lies in the fact that a stable anesthesia is obtained before the start of controlled breathing and the anesthetist then learns the patient's anesthetic requirements before assuming control of respirations.

Complete control depends upon the skillful combination of anesthesia and hypocapnea. Greatly excessive hyperventilation can be detrimental to the respiratory center since under these circumstances, a marked depression occurs from which recovery does not immediately take place. We do not believe that this degree of hyperventilation is likely to take place with the rates and peak pressures we have recommended. Such a depression can be avoided by the maintenance of some slight diaphragmatic activity and the danger minimized by *careful observation of the patient during the return to spontaneous breathing.* There is no reason to believe that respiratory center depression by severe hypocapnea is of equivalent or greater detriment to the patient than anesthetic depression.

CLINICAL APPLICATION

Mechanically controlled respiration has been used in 115 cases and these are briefly summarized in the table. Three (3) groups of observations are not included in the table: (1) the state of the circulation during and at the end of the operative procedure; (2) the respiration in the postoperative period; (3) the postoperative febrile reaction.

Circulation.—In Group 1 of the table there were two patients who showed sharp drops in blood pressure soon after the onset of controlled breathing: 260/160 to 70/40 in one instance and 160/105 to 90/50 in another. These were thought to be the result of hyperventilation and in each instance there was a rise with CO_2 accumulation. In five instances the systolic blood pressure fell to 80 or below when working around the aortic arch while completing a high esophagogastric anastomosis. There was one instance each in Groups 2 and 3 of hypotension associated with hemorrhage, and another in Group 4 when a dense scar was being freed from the heart in a patient with almost no cardiac reserve.

At the end of all procedures the blood pressure was below 90 systolic in three instances in Group 1, once in Group 2, and once in Group 6. All of these except two showed a good initial recovery.

Blood transfusions were used in an effort to replace blood loss. Intravenous crystalloid solutions were used sparingly. Much preoperative attention was directed at correction of malnutrition which was thought to be one of the most important causes of postoperative disturbances in body fluids.

Respiration.—In returning to spontaneous breathing, the respiratory effort was gradually allowed to return during the closure of the chest. There was only one instance in which there was severe respiratory difficulty at the close of the operation. This was due to trapped air in the right pleural cavity after resection of a carcinoma of the midesophagus. There had been a bilateral pneumothorax and air was trapped on the right side of the chest when the esophagogastric anastomosis was pleuralized with mediastinal pleura. Normal breathing resumed as soon as the trapped air was removed. Most of the earlier long and difficult cases showed transient respiratory depression after discontinuing the anesthesia, which probably was due to the level of anesthesia which had been maintained. Now this is being avoided by the use of lighter anesthesia in combination with curare. The average recovery time shown in the chart is much longer in the earlier than in the more recent cases.

Objectively, the respiratory difficulties did not seem severe except in the fatal cases and these were all in patients who showed minimal response to our attempts at preoperative preparation, and were otherwise a difficult group in which to effect any real improvement.

Postoperative Febrile Reactions.—Numerous factors contribute to the postoperative elevation of temperature and it is doubtful whether this will offer any crucial information, but we feel it should be mentioned. The postoperative elevation in temperature seemed to bear little relationship to the operative procedure. The maximum temperature was reached on the first to third postoperative day in the majority of instances with a return to normal by the fourth to sixth day. In spite of the fact that penicillin was used freely pre- and postoperatively, about one-half the patients reached a maximum temperature of between 39° and 40° C. None of these primary elevations were sustained for any length of time in the patients that recovered. A number of patients showed a secondary rise, generally not as high as the primary rise, and lasting for a variable length of time, occasionally associated with the formation of pleural fluid. The infection rate did not seem unreasonable taking into account the poor nutritional state of some of the patients and the degree of pleural contamination in many of the resections of the gastrointestinal tract. In nearly all instances, the chest was closed tightly without suction drainage, fluid and air being removed by needle aspiration when indicated.

GROUP 1. TRANSPLEURAL RESECTIONS OF ESOPHAGUS AND STOMACH

This group afforded the most rigorous test of our method of management. The procedures were of long duration and in several midesophageal lesions, bilateral pneumothorax was produced without incident except in one case after closure as previously mentioned. We feel that these patients were kept in a good physiologic state during operation. The principal limiting factor was the nature of the disease being treated.

GROUP 2. PNEUMONECTOMY

Controlled breathing kept the unobstructed parts of the lung which was undergoing resection somewhat distended and in a functional state as long as the circulation to it was not obstructed. This necessitated some packing off and retraction of the lung during isolation of the vessels. Pulmonary veins and artery were all generally dissected free before ligation and division were carried out. Naturally, when the vascular structures were divided, pulmonary function ceased in the lung which was being resected. Complete control of breathing after ligation and division of the pulmonary vessels has generally not been maintained. However, respiratory effort has been kept sufficiently quiet by augmented breathing so that closure of the bronchus, irrigation of the pleural cavity, and pleuralization of the mediastinum could be carefully carried out without undue haste.

There was one fatality just after the completion of a left pneumonectomy. This was in a patient who originally had severe pneumonia complicated by lung abscess and empyema which eventually resulted in a lattice lung with multiple bronchial fistulae. After phrenicectomy, the lattice lung cavity was surgically closed but intrapulmonary suppuration led to the development of a saccular bronchiectasis of the entire remaining left lung. Severe hemoptysis made it necessary to undertake pneumonectomy, which was carried out with great difficulty but completed only after a rather severe hemorrhage was controlled. After closure of the chest, the patient's condition was poor. The tracheal tube was removed prematurely and the patient asphyxiated from the aspiration of regurgitated gastric content. Resuscitative measures were of no avail.

In two pneumonectomies the left pulmonary veins were ligated and divided intrapericardially, due to the fact that a tumor of the left lower lobe was adherent to the pericardium. One patient made an uneventful recovery, the other died on the seventh postoperative day, apparently of heart failure.

GROUP 3. PULMONARY LOBECTOMY

The group includes two patients with lung abscess, one being fairly acute, and two patients with pulmonary cysts, one of which had been drained on two occasions for an empyema. All lobectomies were done by the individual ligation and division of vascular structures and bronchi. The rhythmic expansion of the pulmonary segment adjacent to the one being resected could be constantly noted as an indication of the patency of the air possages

In one instance there was rather severe hemorrhage from the pulmonary artery. It was thought that the absence of respiratory movements of the thorax facilitated the task of applying pressure and maneuvering until the exact bleeding point of the vessel could be secured.

GROUP 4. PERICARDIECTOMY FOR CHRONIC CARDIAC COMPRESSION

These patients have a marked decrease in cardiorespiratory reserve. Any factors that interfere with the venous return during the period before the scar is removed and the ventricles are freed are dangerous to the patient.[10, 11] Any form of continuous positive pressure anesthesia is to be avoided for this reason. In the earlier cases great care was taken to avoid entering the pleural cavity. More recently the pleural cavity has been widely opened in a small group of patients and intermittent positive pressure used to ventilate the lungs. Even intermittent pulmonary pressure may interfere with blood flow by compression of the pulmonary vascular bed, but if the pleura is open, there should be no added compression of the heart. Tracheal intubation has frequently been omitted when it was thought that a free airway could be maintained without intubation.

GROUP 5. LIGATION OF THE PATENT DUCTUS ARTERIOSUS

These patients were among the least difficult to manage on mechanically controlled breathing. They were young but not so small as to be difficult to manage. The pleura is almost always free from adhesions and the chest wall

SUMMARY OF 115 CASES—

GROUP	OPERATIONS	NO. CASES	DIAGNOSIS	AVERAGE AGE (YR.)	AVERAGE DURATION			
					TOTAL		RESPIRATOR	
					HR.	MIN.	HR.	MIN.
1	Transpleural resections of esophagus and stomach	26	15 Carcinoma of esophagus 2 Strictures of esophagus 9 Carcinomas of the fundus of the stomach	60.5 (except 1 carcinoma fundus, 26)	3	53	2	53
2	Pneumonectomy	11	7 Primary carcinoma lung 3 Chronic inflammation 1 Bronchial adenoma	51.3	3	27	2	42
3	Pulmonary lobectomy	12	8 Bronchiectasis 2 Lung abscess 2 Pulmonary cyst	23.5	3	44	2	23
4	Pericardiectomy	9	Chronic cardiac compression	34.0	3	32	1	39
5	Ligation patent ductus arteriosus	8	Patent ductus arteriosus	15.4	2	20	1	33
6	Exploratory thoracotomy	11	4 Carcinoma esophagus 3 Carcinoma stomach 3 Carcinoma lung 1 Gun shot wound	56.3	1	42	0	59
7	Miscellaneous	10	7 Sympathectomies 1 Cyst mediastinum 1 Achalasia esophagus 1 Diverticulum of esophagus	45.2	2	42	1	00
8	Transpleural vagotomy	18	Peptic ulcer	49.1	2	28	1	19
9	Repair diaphragmatic hernia	10	6 Hiatus hernia 2 Traumatic hernia 2 Congenital hernia	5 mo. to 56 yr.	2	55	1	41

is light and easily expanded. The management of this group of patients most closely approximates our experiences with controlled breathing in the laboratory.

One important practical consideration should be observed when the opening in the pleura is not large, and this is true in most heart operations and also in such operations as thoracic sympathectomies when an opening is made in the pleura. Every effort should be made by the operator to permit a free exchange

AUGMENTED OR CONTROLLED BREATHING

OF ANESTHESIA					
TIME AFTER OPERATION WHEN LISTED AWAKE BY NURSE		EARLY POSTOPERATIVE RESULT (FIRST WEEK)			
HR.	MIN.	SATISFACTORY RECOVERY	DEAD OR IN POOR CONDITION	TIME AND CAUSE OF HOSPITAL DEATHS	OTHER P. O. COMPLICATIONS
1	33	21	5	2 on second P.O. day: from pleuromediastinitis and pneumonia 1 on fourth P.O. day 1 on seventh P.O. day 1 on sixth P.O. day in patient doing well: from pulmonary embolism (autopsy) 1 on seventeenth P.O. day, perforation of aorta at site esophagogastric annastomosis 1 on eighteenth P.O. day in patient who improved initially, then declined. There was necrosis of gastric tube and mediastinitis (autopsy) 6 died later in hospital of residual carcinoma	1 developed partial small bowel obstruction at site of jejunostomy, relieved by Miller-Abbott tube 2 developed into empyema
2	44	9	2	1 death 20 min. P.O. shock and aspiration (see text) 1 death sixth day heart failure	1 empyema in 4 weeks due to opening of bronchus
2	30	12	0	None	1 empyema in 4 weeks with development of bronchial fistula (chronically infected pulmonary cyst) 2 localized empyemas
1	48	8	1	1 in 24 hr. in patient with calcified myocardium; 1 in 6 weeks, generalized miliary tuberculosis	None
2	10	8	0	None	None
0	57	7	4	2 on first P.O. day, shock, pleuritis 1 on second P.O. day, pneumonia 1 on seventh P.O. day, pneumonia All advanced inoperable malignancies	Patients continued, course unchanged, and left hospital
2	25	10	0	1 on twelfth P.O. day in severe hypertensive, none that developed wound infection and uremia after sympathectomy	None
1	36	18	0	1 on twelfth P.O. day from Guillain-Barre syndrome with respiratory paralysis; autopsy showed infectious neuronitis of spinal cord and medulla	None
1	58	10	0	None	1 bilateral thrombophlebitis with multiple pulmonary emboli (large traumatic left diaphragmatic hernia five years' duration

of air into and out of the pleural opening to facilitate lung expansion by the intermittent pulmonary pressure. There is sometimes a tendency on the part of the surgeon to cover the opening with tapes and retractors. This interferes with the expansion of the lung in the air-filled hemithorax and, therefore, with the control of breathing. This interference can be avoided by the maintenance of an open pneumothorax during the period of controlled breathing.

GROUP 6. EXPLORATORY THORACOTOMY

This procedure was carried out in a heterogeneous group of patients, most of whom had inoperable lesions, mostly malignancies. Many of these patients had synechiae of the pleural cavities and fixation of the mediastinal structures. Mechanical control of breathing was more difficult in this group before the use of curare. Better mechanical ventilation was possible after a considerable part of the lung on the side of the pneumothorax was freed from the chest wall so that the volume change in the lung could be independent of the movement of the chest wall.

GROUP 7. MISCELLANEOUS

There are no special problems in these patients that are not discussed in connection with the other groups.

GROUP 8. VAGOTOMY

As a group, these patients should offer an excellent opportunity to observe the effects of anesthesia alone since the effect of the disease and of the operative procedure are minimal. However, to obtain highly significant data about the role of technique of anesthesia would require many more cases. One death following this procedure was due to an ascending myelitis of the spinal cord, proved by autopsy, and in all probability not related to the anesthesia. This probably represents a very unusual complication and the possibility must be considered that the myelitis was in some way related to the operative procedure.

GROUP 9. DIAPHRAGMATIC HERNIA

The transpleural approach has been used in all diaphragmatic herniae. All patients did well except one who developed a severe bilateral thrombophlebitis, the first sign of which was a massive pulmonary embolus, which the patient survived.

SUMMARY

Physiologic principles involved in the respiration of open pneumothorax are discussed and the evolution of augmented and controlled breathing by mechanical means is reviewed. Experiences with 115 patients are tabulated and discussed. The interrelationship of the effects of hypocapnea, ether, and curare in the mechanical control of breathing are discussed.

CONCLUSIONS

As a result of our experience, we believe that there is a need for continued development and application of mechanically controlled respiration in thoracic surgery. However, it should be emphasized that a mechanical device is in no way a substitute for skill, knowledge, and experience in the management of anesthesia for thoracic surgery. It merely offers standardized control with a range and variability of action sufficient to meet the needs of the patient as determined by the anesthetist.

It should be pointed out that, as far as determining the quality of our method of management is concerned, the study of the present small heterogenous group of patients would only be of value in bringing to light serious hazards of the method. No such complications of our method were noted. Whether the method, as outlined here, will be of any permanent value will be determined by future development and application.

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DISCUSSION

DR. CLAUDE S. BECK, Cleveland, Ohio.—I hesitate to comment on this subject because thoracic surgeons have done so many major operations without mechanical respiration. On those occasions when you do get into difficulty during operation you have the anesthetist compress the gas bag a few times. The heart action improves as does also the color, and the surgeon almost always is able to proceed to a successful conclusion of the operation. There are occasions, however, when the course of events is not as favorable as one might desire; compression of the gas bag by the anesthetist does not restore cardiorespiratory function.

I remember well a patient whose life was saved by the use of mechanical respiration. This patient had increased intracranial pressure and stopped breathing when he was placed on the operating table. An intratracheal tube was inserted and mechanical respiration was given. The skull was opened and a meningioma was removed from the tentorium. This required several hours and during this period respiration was carried out by the breathing machine. Toward the end of the operation the patient was breathing on his own. I do not believe that compression of the gas bag by hand would have been adequate to carry this patient along for several hours before his breathing center regained function and I believe mechanical respiration by means of the respirator was a factor in recovery.

The anesthetist can help the patient a great deal by manual compression of the gas bag when the only requirements are several full inflations of the lungs. If either respiration or circulation is threatened with a breakdown over a long period of time, then it is my feeling that manual compression of the gas bag is not adequate. In this situation the lungs should be inflated and deflated to the proper degree with each respiration.

When respiration ceases or when the heart stops beating, then proper pulmonary ventilation becomes a requirement. This can be accomplished by the use of a respirator. Dr. Mautz has made a satisfactory respirator. It works on the principle of compression of a gas bag by means of air pressure rhythmically applied to the bag. The fact that air pressure is necessary limits its use. In the Army hospitals and in many civilian hospitals air pressure has not been available in the operating rooms and I hope we can make a more simple respirator which can be run by an electric motor.

I want to make this concluding remark: I believe every operating room should be equipped with a respirator which can take over the job of breathing for the patient.

Addendum.—On June 23 I operated upon a patient for funnel chest. At the conclusion of the operation the blood pressure disappeared and the heart beat could not be felt. Mechanical respiration was given and massage of the heart was carried out. Electrocardiogram showed a dying heart in ventricular fibrillation. It was one hour and ten minutes before we were able to defibrillate the heart and mechanical respiration and massage were necessary for a considerably longer period of time after the ventricles were defibrillated. The beat was very weak but after another hour it became stronger. Complete recovery followed. In this instance, which in so far as I know, may be the first case of successful defibrillation, mechanical respiration was a requirement for recovery.

DR. FREDERICK G. KERGIN, Toronto, Ont.—We have been concerned about the question of anoxia during certain thoracic operations, and particularly in those cases where the opposite side is the site of bronchiectasis, and even more particularly in the second side of bilateral cases.

In order to study this problem we have used a machine called the oximeter, which gives continuous estimations of the oxygen saturation during operation. In fifty-eight observations on major cases we have found that during the course of pneumonectomy or lobectomy there is a steady, slow fall in the degree of arterial oxygen saturation to 80 or 85 per cent, and in some cases to 60 or 70 per cent—levels which are probably dangerous. We have found that this can be compensated almost invariably by positive pressure anesthesia of 15 mm. of mercury. This appears to be due to a gradual atelectasis in the contralateral lung, associated with a shift in the mediastinum.

We are coming now to the point that Sauerbruch suggested many years ago, operating with positive pressure on the contralateral lung. Our observations will be continued and will be reported later.

DR. F. R. MAUTZ, Cleveland, Ohio.—I would like to emphasize just one thing which I did not have an opportunity to go over in detail in the presentation.

It isn't enough that we take care of anoxia. We must get the CO_2 out, and there have been reports in this connection, especially with the use of cyclopropane, in which very high levels of CO_2—over 100 volumes per cent—have been found after several hours of anesthesia, with a shift of the pH to below 7.9, and I think there is a real difficulty here of which we do not have any good clinical evidence in some of these long transpleural operations.

CANCER OF THE LUNG

INTERVAL AND LATE RESULTS OF OPERATION IN RELATION TO TOPOGRAPHY AND GROSS PATHOLOGY

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THE literature on interval and late results after pulmonary resection for carcinoma consists largely of statistics pertaining to survival for varying periods of time. It lacks information as to a possible relation of the gross pathology or the topography to the results and, therefore, leads to the assumption that one has no significant bearing upon the other. Occasionally an author relates certain microscopic features to prognosis but, in the main, the literature is decidedly uninformative as to a link between the type of tumor and the result of operation, as well as between the extent of regional lymph node involvement and the operative result. As to the question of lobectomy, that is usually dismissed with the statement that only pneumonectomy can be anticipated to offer a cure for cancer of the lung.

At two previous meetings of The American Association for Thoracic Surgery, a topographic classification of cancer of the lung was proposed, and arguments were advanced to support our contention that the classification should be used as a basis for operability and, therefore, for prognosis. We now submit an analysis of the results of operation based on such a classification, hoping to prove its usefulness. Furthermore, we hope to show that prognosis based on microscopic features cannot be made with any assurance, and that lobectomy based on topographic features has its place in the surgery of cancer of the lung.

We feel that this analysis is timely; our period of observation of a sufficient number of cases, fifty-two recoveries after pneumonectomy and lobectomy, is of such duration as to warrant a consideration of interval and late results after both procedures. The fifty-two cases comprise consecutively operated patients who were discharged from the Hospital after pulmonary resections between January, 1935, and December, 1945. There are no omissions. The follow-up is 100 per cent, none of the patients having disappeared from observation. An eleven-year survival after pneumonectomy for sarcoma, and other more or less prolonged survivals after operations for other forms of malignancy are excluded. Two cases of minute bronchial carcinoma are also excluded, but because of their unique character they are reported at the end of this paper.

Operations were performed on the basis of favorable topographic and gross pathologic features. As a rule, age or general condition played no role when the topography and pathology were conducive to surgery. Patients with involvement of hilar lymph nodes were given resection when surgical eradication appeared to be feasible, but, in our opinion, a frozen hilus or invasion of

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mediastinal nodes rendered patients inoperable. So-called palliative pneumonectomy was not practiced. There were a few exceptions in which involved *mediastinal nodes* were *discovered* after the hilus had been severed in whole or in part. It should be stated here that none of these patients survived more than one year.

The group subjected to lobectomy had circumscribed tumors situated in the periphery of lobes, in which regional lymph node involvement did not exist or was thought to be absent. Reference will be made to errors in interpretation and judgment in this group, which, in a few instances, led to incorrect management. Some of the tumors were of unusually large size, and virtually a whole lobe was involved in a few cases. Nevertheless, if a clean dissection of the hilar structures could be performed, lobectomy was adhered to on the basis of topographic features and the supposed absence of lymph node involvement.

Peripherally invasive tumors were subjected to resection regardless of their size or the extent of involvement of the thoracic cage if it was thought that excision beyond tumor tissue was possible. There are included a number of instances of invasive growths, paravertebrally situated, in which complete excision was questionable because of the juxtaposition of the vertebral column. Lobectomy may be termed a subordinate part of the surgical procedure in many of these cases of peripherally invasive cancer, attention having been focused on the excision of the involved portion of the thoracic parietes. Indeed, in some instances only partial lobectomy for the relatively, or actually, insignificant pulmonary component of the tumor was performed.

For the purpose of this paper, the topographic classification is in three groups. They will be defined briefly, with the understanding that there are occasional instances in which doubt exists as to the precise classification.

GROUP I. MAIN AND BRANCH BRONCHUS CANCERS

They are infiltrative, with ill-defined limits (diffuse). The lesion may be ulcerative or may involve the bronchial wall by submucous extension. Bronchoscopic diagnosis is usually positive, particularly in the main bronchus cancers. By the time these cases, especially the main bronchus cancers, come to operation, the regional lymph node involvement is likely to be extensive. Branch bronchus circumscribed tumors belong in Group II.

GROUP II. CIRCUMSCRIBED CANCERS

These are infiltrative microscopically, but grossly appear encapsulated and distinct from the adjacent pulmonary parenchyma. The roentgen appearance is characteristic. Essentially symptomless (except for the branch bronchus variety), erosion of the tumor into a large bronchus may provide a positive bronchoscopy. With such an extension, there may be hemoptysis or atelectasis. Regional lymph node involvement is likely to be limited; it may occur late in the course of the disease, or it may be nonexistent, even with extremely large growths.

GROUP III. PERIPHERALLY INVASIVE CANCERS

These tumors are more or less grossly circumscribed on their medial aspect and thus are prone to cast a characteristic shadow on the x-ray film. Peripherally, they invade adjacent structures, such as the thoracic parietes, superior aperture of the thorax, pericardium, or diaphragm. Bronchoscopy is negative. Hilar node involvement is unusual, but involvement of the lymphatics and nodes in the area of peripheral invasion may be anticipated.

The fifty-two cases were divided as follows: (Table I) Group I, main or branch bronchus cancer, twenty-one cases; Group II, circumscribed cancer, eighteen cases; Group III, peripherally invasive cancer, thirteen cases.

In the twenty-one patients in Group I, pneumonectomy was performed in twenty and a lobectomy was done in one. In the latter it was thought that the tumor was of the circumscribed type. In Group II, there were twelve lobectomies and six pneumonectomies, and in Group III, twelve lobectomies and one pneumonectomy. Table I shows that lobectomy was confined entirely to the circumscribed and peripherally invasive groups. Thus, of the fifty-two patients, twenty-seven had pneumonectomies and twenty-five, lobectomies.

Although there were twice as many pneumonectomies as lobectomies performed during the eleven-year period, there was an approximately equal number of operative survivals from each type of operation. This was due to the lower operative mortality following lobectomy. It might not be amiss to point out that lobectomy appeared to be the only operation that could be attempted in a few instances because of the age and general condition of the patient.

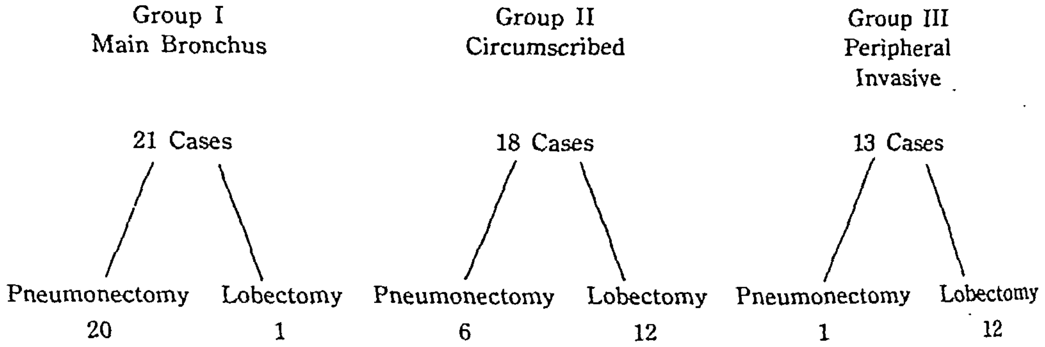
Detailed examination of the groups reveals the following: (Table II) Group I: Of the twenty-one patients with main and branch bronchus carcinomas, seven are alive and free from recurrence. Recurrence took place in the single lobectomy, performed in error, as noted above. Of these seven patients, three had no regional node involvement, and in four the involvement was limited to from one to three small nodes. Of the fourteen patients who developed recurrences or metastases, the surgical specimens revealed that eight had lymph node involvement and six had none. Of the eight patients with node involvement at the time of operation, four developed recurrences in the regional nodes and four developed blood-borne metastases. Of the six without node involvement, one developed regional node recurrence and five developed blood-borne metastases. The almost equal number of patients with and without node involvement in the nonsurvival group is contrary to expectations. Nevertheless, it is readily explained by the high percentage of blood-borne metastases in this group, and especially in those patients without node involvement.

In Group II, circumscribed cancers, seven patients are alive and free from recurrence. There were twelve patients with lobectomies, of which four are alive and well, and six with pneumonectomies with three survivals. The analysis is to be seen in Table III. Of the eighteen patients in this group, four had involved nodes at time of operation, three of them being limited to a single node. Of these four, only one, a patient with pneumonectomy, is alive. Of the fourteen without nodes, six are alive; two after pneumonectomy and four after lobectomy. There was one patient who died six months postoperatively due to an accident. At post-mortem examination no recurrence was found.

In order to ascertain whether the eight patients in this group who died following lobectomy might have had a better result with a pneumonectomy, an analysis of their causes of death was made. That three required pneumonectomy was evident at operation, but because of untoward developments during operation a rapid lobectomy was performed. In three additional cases, early distant lymph node metastases indicate that even pneumonectomy would not have been curative. In two, late lymphatic recurrences suggest that pneumonectomy might have been curative. The unexpectedly high incidence of lymphatic involvement as the cause of recurrence parallels its relatively low incidence in Group I cases. This is all the more surprising because the Group II tumors so often are silent, with blood-borne cerebral metastases producing the first symptom of disease.

TABLE I

52 Cases

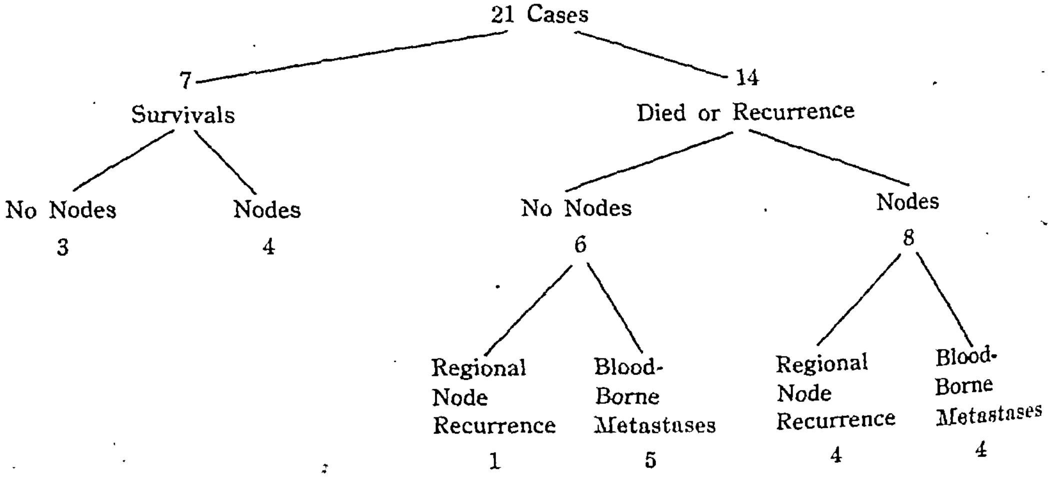


Pneumonectomy 27
Lobectomy 25

TABLE II

Group I

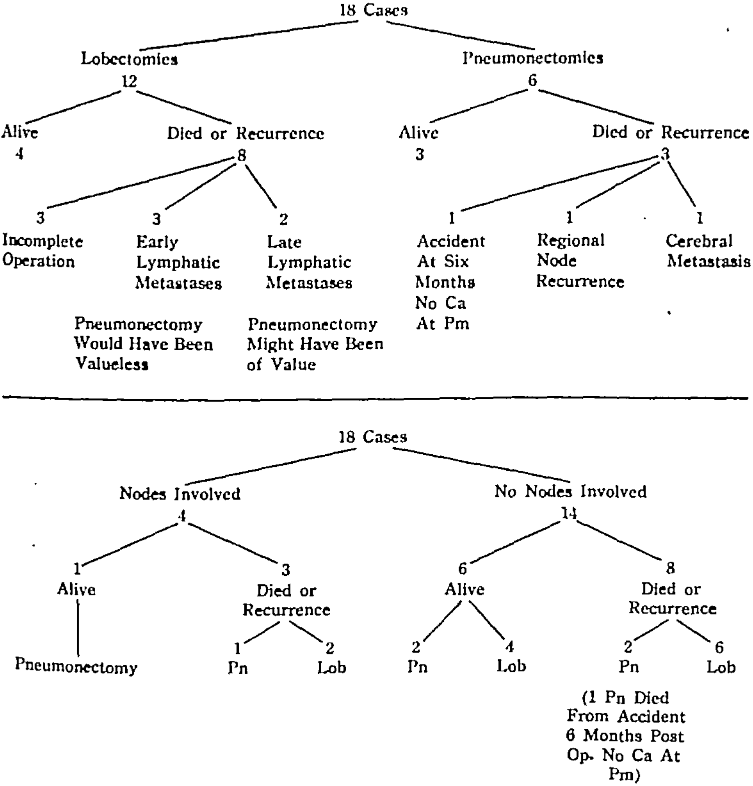
Main and Branch Bronchus



In Group III, peripherally invasive cancers (Table IV), none of the patients had node involvement, but only three survived (one of these died four years postoperatively from a main bronchus carcinoma of the other lung, which was regarded as another primary tumor). The cause for seven failures was local recurrence in the area of peripheral invasion of the thoracic wall or other structures. This occurred in spite of wide excision of the involved areas.

TABLE III

Group II
Circumscribed



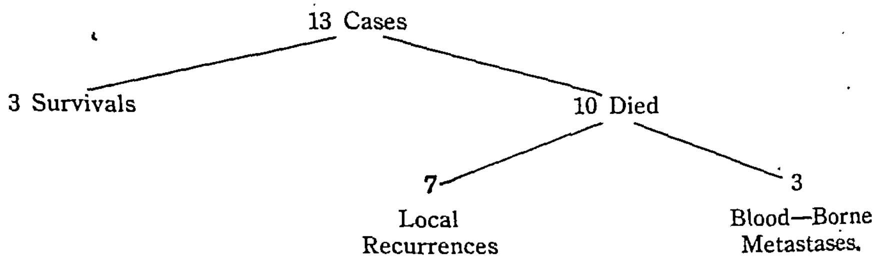
Therefore, even wider block dissections appear warranted. Furthermore, the recurrence at the site of peripheral invasion establishes that pneumonectomy could not have been any more curative than lobectomy. Blood-borne metastases were the cause of failure in the remaining three patients.

The duration of survival of the seventeen "alive and well" patients is seen in Table V. It should be noted that all survivals, with a single exception, are of more than two years' duration. Concerning the large number of patients in the two-to-three- and three-to-four-year groups, some of these may still develop recurrences and die from their original disease. That this may occur cannot be gainsaid. On the other hand, an analysis of the time of recurrence, metastasis, or death in thirty-four cases (Fig. 1) points to the likelihood of an indeterminate freedom from recurrence after two years. As can be seen, the great preponderance of recurrences or deaths occur in the first year, with only a few in the second year, and a single exception in the third year. The last mentioned is a patient who had had a lobectomy for a circumscribed tumor without node involvement. Two and three-quarter years later he developed enlargement of a contralateral supraclavicular node. This was removed and showed metastatic carcinoma. There was no other evidence of metastasis. If these observations on the sharp line of cleavage at the end of the two-year period are borne out by larger statistics, as well as by further follow-up of this series, it would appear that cancer of the lung has a distinctive and favorable ultimate prognosis if patients are well two years after operation.

TABLE IV

Group III

Peripherally Invasive



12 Lobectomies
1 Pneumonectomy

All Without Node Involvement

Most observers base prognosis on the microscopic features of the tumor. An analysis of our cases (Table VI) shows that the squamous cell carcinomas were fairly evenly distributed among the three groups, and that the adenocarcinomas comprised a high percentage of the circumscribed tumors. The survival rate is slightly higher for the adenocarcinomas as compared with the squamous cell carcinomas (45 per cent to 29 per cent). Included in the squamous cell carcinomas are five cases of the undifferentiated type. Two of these patients are alive and well. The follow-up in our series does not indicate that the microscopic features of cancer of the lung are pertinent to the prognosis after radical excision.

Survival in relation to topographic classification is shown in Table VII. If we omit the three cases in which insufficient lobectomy was performed, we have a survival rate of almost 50 per cent in circumscribed cancer as compared with 33 per cent for main bronchus cancer. Thus, a widely held view that the ultimate prognosis after operation for circumscribed cancer of the lung is poor is not borne out in this series.

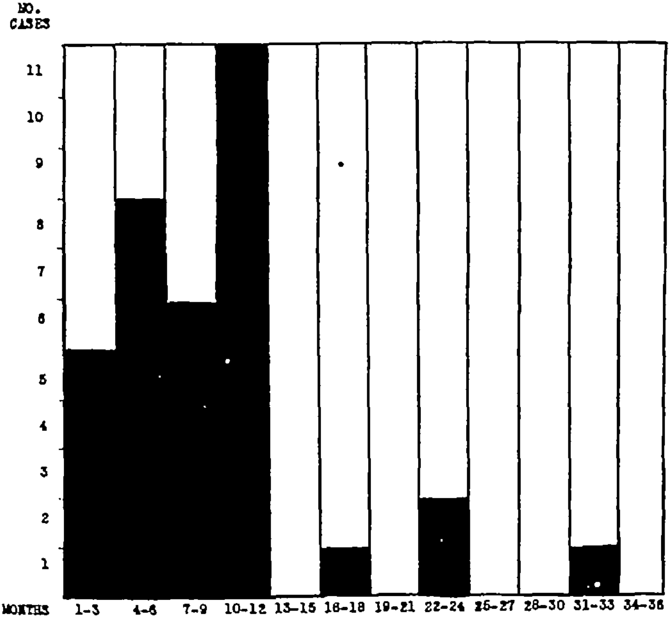


Fig. 1.—Time of appearance of recurrence, metastasis, or death in thirty-four cases.

There are many who are of the opinion that lobectomy has no place in the surgical therapy of pulmonary carcinoma. It has long been our thesis that because of the frequent absence of regional node involvement in the circumscribed and peripherally invasive groups, lobectomy has a place in the surgery of these types of cancer. In this series of fifty-two cases, there are ten survivals after twenty-seven pneumonectomies and seven survivals after twenty-five lobectomies (Table VIII). These figures substantiate our contention that lobectomy has its indications in the surgery of pulmonary carcinoma. However, lobectomy should be limited to cases without node involvement and in which the tumor is not in close proximity to the hilus. It is obvious that not only lower mortality but also better functional results can, in general, be anticipated after lobectomy as compared with pneumonectomy.

TABLE V. DURATION OF SURVIVAL

YEARS	NO. CASES
1-2	1
2-3	7
3-4	4
4-5	1
5-6	2
7-8	2
Total	17

TABLE VI. MICROSCOPIC PATHOLOGY IN FIFTY-TWO CASES

	SQUAMOUS CELL CARCINOMA*	ADENOCARCINOMA	SMALL CELL CARCINOMA
Main bronchus	15	3	3
Circumscribed	11	7	
Peripherally invasive	12	1	
Total	38	11	3

MICROSCOPIC PATHOLOGY IN SEVENTEEN SURVIVALS

	NO.	%
Squamous cell carcinoma*	11	29
Adenocarcinoma	5	45
Small cell carcinoma	1	33

*Included in the squamous cell carcinomas are five of the undifferentiated type. Two of these are alive and well.

TABLE VII. SURVIVAL IN RELATION TO GROUP CLASSIFICATION

	NO. CASES	SURVIVALS	%
Main bronchus	21	7	33.3
Circumscribed	18	7	38.8
Peripherally invasive	13	3	23

TABLE VIII. SURVIVAL IN RELATION TO TYPE OF OPERATION

	NO. CASES	SURVIVALS	%
Lobectomy	25	7	28
Pneumonectomy	27	10	37

The following two cases, previously referred to, are unique instances of minute bronchial cancer. Although both patients are alive and well, they have not been included in the statistics because of the peculiar nature of their pathologic findings.

D. Z., a man aged 63 years, was admitted to The Mount Sinai Hospital on Dec. 22, 1943, with a history of an attack of pneumonia, with roentgen evidence, two months previously. Subsequently, he had a slight cough, substernal pain, and dyspnea. He had an old cardiac lesion. X-ray examination of the chest was essentially negative. He was bronchoscoped and a ''bump'' was seen at the orifice of the right upper lobe bronchus. A specimen was removed and was reported ''squamous cell carcinoma.'' Right pneumonectomy was performed, and although the postoperative course was complicated by cardiac decompensation, he recovered; and he is alive and well today.

Examination of the specimen failed to reveal any evidence of carcinoma. Many sections from the biopsy site were examined. A number of pathologists who reviewed the original slide were all in agreement as to the diagnosis of malignancy. A careful investigation ruled out any possibility of a mix-up in specimens or slides.

M. W., a man of 47 years, was admitted to The Mount Sinai Hospital on Feb. 4, 1944, with a history of cough for two years. Because of a persistent shadow in the region of the right middle lobe on x-ray examination, he was bronchoscoped, and a biopsy from the right middle lobe bronchus showed "squamous cell carcinoma." Right middle lobectomy was performed on Feb. 23, 1944. The lobe was found atelectatic and shrunken. Immediate examination of the specimen showed no tumor; therefore, another segment of the bronchus was removed, but this also appeared negative for carcinoma. Diligent microscopic examinations of these specimens failed to reveal any evidence of malignancy. A recheck on the original biopsy specimen substantiated the diagnosis. An empyema developed postoperatively; after this was drained and the patient was convalescent, bronchoscopy was again performed. A biopsy taken from the stump of the middle lobe bronchus showed "Fragments of bronchial mucosa showing metaplastic squamous cell epithelium and a few isolated irregular cells. No evidence of tumor." The patient is alive and well today.

SUMMARY AND CONCLUSIONS

1. Interval and late results are reported on fifty-two patients who survived operation. They have been classified in three groups. The operations performed in each were: Group I, twenty pneumonectomies and one lobectomy; Group II, twelve lobectomies and six pneumonectomies; Group III, twelve lobectomies and one pneumonectomy.

2. In Group I (the main bronchus cancer), there were no survivals in patients with extensive regional node involvement in the specimen. Involvement was limited, or absent, in the seven patients who survived. An unexpectedly high occurrence of blood-borne metastases was the fatal factor, especially in the cases without lymph node involvement at the time of operation.

3. In Group II (circumscribed cancer), lymph node involvement at the time of operation was rare, yet lymph node metastases as the cause of death was unexpectedly high. The incident of blood-borne metastases was surprisingly low. Lobectomy is not curative in the presence of lymph node involvement.

4. Despite the absence of regional node involvement, the results were poor in Group III (peripherally invasive cancer), due to local recurrence, usually in the thoracic parietes. Results might be better with wider excision of the thoracic wall.

5. The microscopic features of cancer of the lung bear no significant relation to the ultimate postoperative prognosis.

6. The prognosis after a correctly selected operation for circumscribed cancer of the lung is better than that for main bronchus cancers.

7. Lobectomy is a properly conceived operation which may be curative for circumscribed and peripherally invasive carcinoma of the lung.

8. A substantial proportion of good interval and late results has been achieved by pneumonectomy or more conservative operations performed on the basis of the topographic features of the neoplasm. There is full justification for an enthusiasm for the surgery of cancer of the lung when eradication is based upon the recognition and consideration of the topographic features.

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2. Neuhof, Harold, Rabin, Coleman B., and Sarot, Irving: A Topographic Classification of Cancer of the Lung, With Special Reference to the Surgical Implications of the Circumscribed Variety, J. Thoracic Surg. 11: 388, 1941-2.

CARCINOMA OF THE LUNG

Factors Affecting Survival After Resection of Cancer of the Lung

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FIFTEEN years have elapsed since the first successful bilobectomy by Churchill and the first successful pneumonectomy by Graham for carcinoma were reported by the operators. Since those reports, various clinics have slowly accumulated a sufficient number of operative cases to permit numerical examination of the fate of the hospital survivors and critical study of the factors which seem to affect the time and rate of survival. This paper presents an analysis of one such group of cases.

In the period of fifteen years ending Dec. 31, 1945, a diagnosis of carcinoma of the lung was established by microscopic proof in 182 cases at the Lahey Clinic. One hundred twenty-six patients (69.2 per cent) were inoperable for various reasons. A resection of the lesion by means of a pneumonectomy or a lobectomy was done in fifty-six cases (30.8 per cent; Table I). Eight (14.3 per cent) of these fifty-six patients died postoperatively in the hospital (Table II) from the causes stated in Table III. The over-all hospital mortality of 14.3 per cent has been reduced during the last five years under consideration to 5.1 per cent in thirty-nine resections.

The results in the forty-eight patients on whom resection was carried out and the patients discharged alive from the hospital are correct through Dec. 31, 1946. Patients on whom operation was performed in the year 1946 were excluded in order that this study of clinical outcome might not be complicated by observations of less than one year's duration. From the forty-eight cases, an attempt is made to assay factors related to the carcinoma, its behavior, and its treatment, which appear to affect survival time in the meager light of our present knowledge of cancer.

1. RESULTS OF ALL RESECTIONS (Chart 1)

This chart and those which follow are constructed in a similar manner. The completed years since the resection was done are represented on the abscissa and the number of cases on the ordinate. The rectangles demonstrate by height the number of patients operated upon a period of years previously, corresponding to or longer than the five yearly periods considered. The shaded portion of each rectangle illustrates the number and the percentage of patients surviving for the same or a longer period. The lowermost or black portion, where present, shows the number and the percentage of patients who were operated upon as long or longer ago than the respective years indicated, living and well on Dec. 31, 1946.

From the Department of Surgery, The Lahey Clinic, Boston.

Read at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

TABLE I. CARCINOMA OF LUNG

	CASES	PER CENT
Proved	182	
Inoperable	126	69.2
Resection	56	30.8

TABLE II. CARCINOMA OF THE LUNG: FACTORS AFFECTING SURVIVAL AFTER OPERATION

	CASES	PER CENT
Resected cases	56	
Hospital deaths	8	14.3
Discharged alive	48	85.7
Hospital mortality, last 5 years (2 in 39)		5.1

TABLE III. CARCINOMA OF LUNG: CAUSES OF HOSPITAL DEATH IN FIFTY-SIX RESECTIONS

Pulmonary Embolus	1
Cardiac Failure	1
Pneumonia and Atelectasis	3
Hemorrhage	2
Fistula and Empyema	1
Total	8

Of forty-eight patients on whom resection was done more than one year previously, thirty-one (64.5 per cent) survived for more than one year, and fifteen (31.2 per cent) are at present (Dec. 31, 1946) living and well for more than one year. Of seventeen on whom resection had been done more than five years previously, six patients (35.3 per cent) survived for more than five years, and four (23.5 per cent) are now living and well for more than five years. The microscopic slides of specimens from all patients surviving and well have been critically reviewed to be sure that no case of bronchial adenoma was unwittingly included in this study. This first chart represents the composite results of resection, without regard to any of the other variations considered in the subsequent charts.

2. DURATION OF SYMPTOMS (Chart 2)

The problem of earlier diagnosis is constantly with us. A majority of the 126 patients on whom operation was not done (69.2 per cent) had conditions which were, no doubt, technically inoperable because of lateness in diagnosis, but in the specifically limited scope of this paper the influence of symptom duration upon prognosis after resection is shown in Chart 2. Twenty patients had symptoms for less than six months in the group operated upon one year or more previously. Thirteen (65 per cent) survived a year or more and eight (40 per cent) are living and well. Two (33.3 per cent) of six operated upon for more than five years survived five or more years, but none are now alive and well. In the group with symptoms for seven to twelve months there were twenty patients operated upon more than one year previously, of whom thirteen (65 per cent) survived for more than one year, and five (25 per cent) are now alive and well. In seven cases more than five years has elapsed since operation. Three patients (42.8 per cent) survived for more than five years and two (28.5 per cent) are now living and well for more than five years. Symptoms persisted for more than one year prior to operation in a group of eight patients operated upon more than one year previously. Five (62.5 per cent) of these survived a year or more and two (25 per cent) are still alive and well. Only one of four patients operated upon five years previously survived for as long

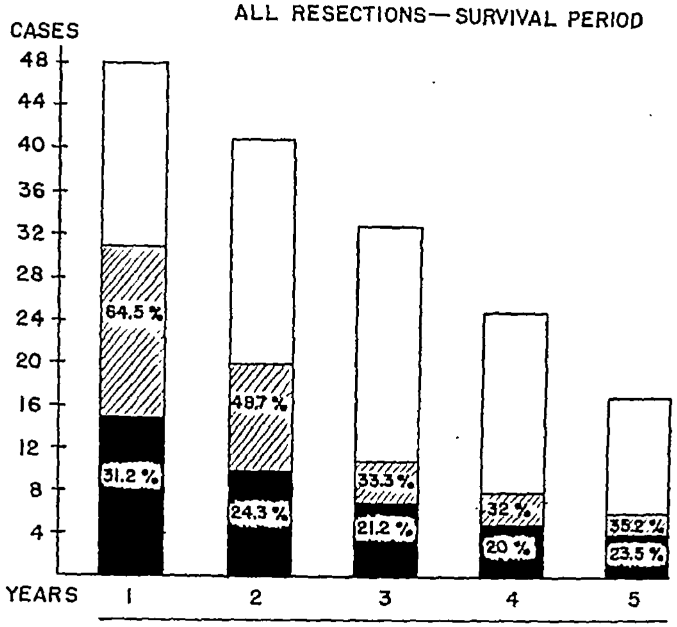
ALL RESECTIONS—SURVIVAL PERIOD

Chart 1.

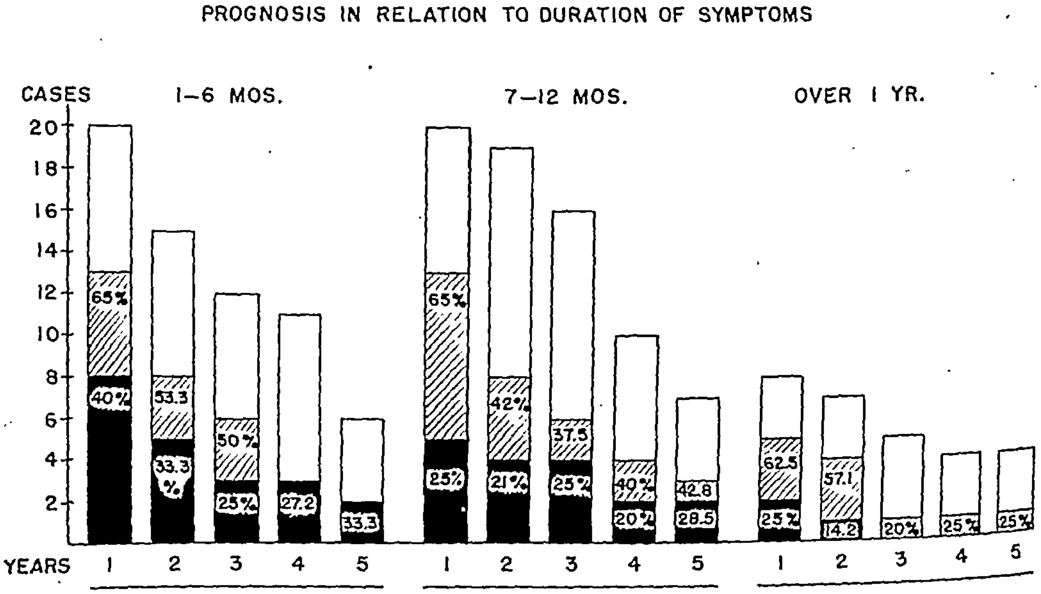
PROGNOSIS IN RELATION TO DURATION OF SYMPTOMS

Chart 2.

as one year, and that patient is now dead. It is thus apparent that any patient who has a pulmonary carcinoma resected and leaves the hospital alive has approximately a 60 to 65 per cent chance of surviving one year thereafter, regardless of the prior duration of symptoms. Examination of the intervening columns for two, three, and four years indicates the accelerated rate at which patients *who have had symptoms of long duration prior to resection succumb.* The fact is not readily adaptable to visual presentation on a chart, but it was apparent from examination of the individual records that many patients with the more anaplastic types of tumors were seen when their symptoms were of less than six months' duration. Similarly, it is obvious by hindsight that several of the patients with slowly growing tumors had not presented themselves until they had had symptoms for between seven and twelve months. It is believed that these observations explain the better survival rate in patients with symptoms of seven to twelve months for the group at present living and well than for those with symptoms of less than six months.

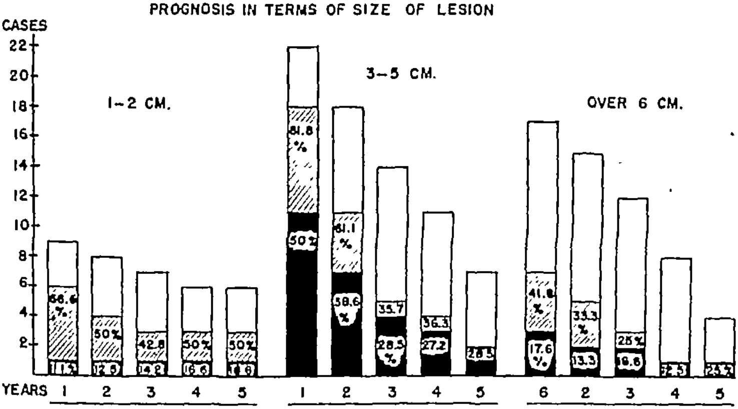

Chart 3.

3. PROGNOSIS IN TERMS OF SIZE OF LESION (Chart 3)

Every gastric surgeon is familiar with the tiny carcinoma of the stomach which is easily resectable but the patient dies of recurrent or metastatic malignancy within a year or eighteen months. He can by comparison recall other cases with large fungating lesions that have not extended outside the stomach grossly and can cite an occasional patient living and apparently well three or four years later. An attempt to correlate survival with the size of the pulmonary lesion as determined by the pathologist's measurement of the excised specimen indicates some similarity to gastric carcinoma. For purposes of analysis the carcinomas were segregated into groups containing those less than 2 cm., those less than 5 cm., and those over 6 cm. in diameter.

Chart 3 illustrates this discrepancy from common-sense expectation in respect to size of the lesion for short-term survival periods.

One (11.1 per cent) of nine patients with lesions less than 2 cm. in diameter is alive and well for more than one year as is one (16.6 per cent) of six patients who had had operations more than five years previously. Of the patients with carcinomas between 3 and 5 cm. in diameter, eleven (50 per cent) of twenty-two are living and well for more than one year as are two (28.5 per cent) of seven patients who had had operations more than five years before. Of the patients with growths more than 6 cm. in diameter, three (17.6 per cent) of seventeen are alive and well for more than one year, as is one (25 per cent) of four patients operated upon more than five years ago. It, therefore, appears that the size of the lesion as determined by actual measurement of the excised specimen is an unreliable indicator of prognosis. It is suggested that the frequently attending pneumonitis and signs of collapse make the apparent size of the lesion as judged from examination of a radiographic film even less reliable as an aid in estimating preoperatively the chance of survival in an individual case.

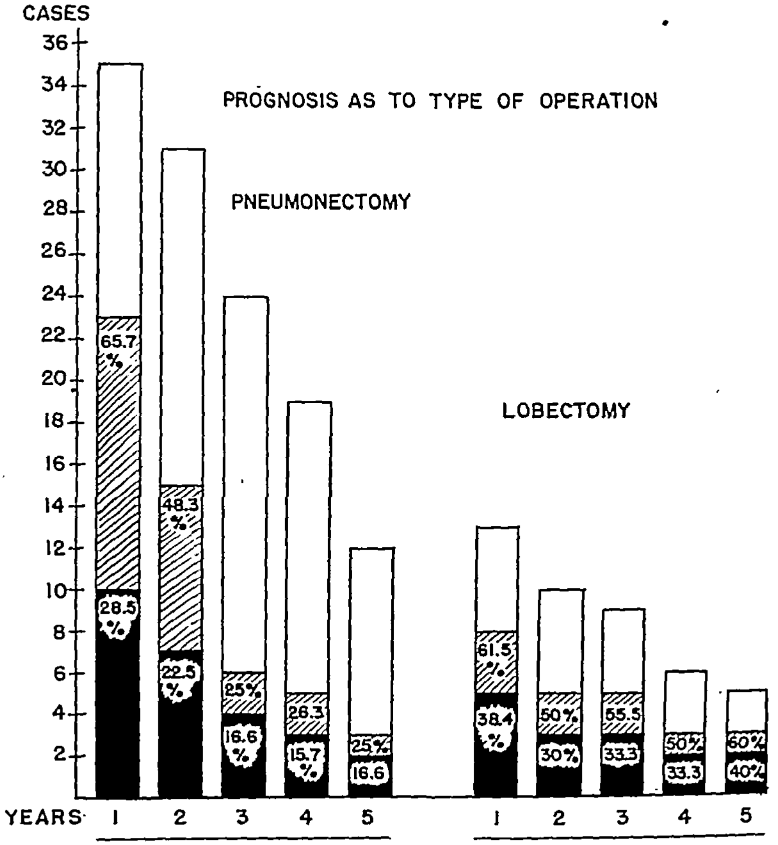

Chart 4.

4. PROGNOSIS IN REFERENCE TO TYPE OF RESECTION DONE (Chart 4)

Based upon the philosophy that mass removal of the involved organ and contiguous lymph nodes represents the nearest attainable surgical approach to the ideal in cancer therapy, it has been logical to assume that pneumonectomy offers a preferable type of treatment to any more limited type of resection in cancer of the lung. No significant difference of viewpoint from this concept in working practice is implied. For upper lobe lesions, however, where the lymph drainage pathways are characteristically directed toward the azygous nodes, and for certain peripherally situated lower lobe lesions with no demonstrable nodal involvement, we have for several years been of the opinion that a lobectomy offered almost equal chance of long survival, with the advantages of appreciably lessened operative risk and greater functional capacity. As indicated in Chart 4, thirty-five of these forty-eight resections were accomplished by pneumonectomy and thirteen by lobectomy. Twenty-three (65.7 per cent) of the thirty-five patients on whom pneumonectomy was done one year or more previously have survived that length of time and ten (28.5 per cent) are still living and well. Of twelve patients treated by pneumonectomy more than five years ago, three (25 per cent) survived for five years and two (16.6 per cent) are now alive and well. These figures may be compared with those for the lobectomy group of thirteen cases with operation more than one year previously, of which eight patients (61.5 per cent) survived for more than a year, and five (38.4 per cent) are still alive and well. Of five patients on whom lobectomy had been done more than five years previously, three (60 per cent) survived five or more years, and two (40 per cent) are still alive and well. It is scarcely necessary to call attention to the fact that the patients with more advanced disease were treated by pneumonectomy.

5. SURVIVAL RATE IN RESPECT TO NODAL INVOLVEMENT (Chart 5)

In cancer of other organs, such as the breast and rectum, it has long been known that the presence or absence of involvement of lymph nodes is a preponderant if not determinative consideration in estimating the individual patient's chance for long survival. It was assumed early in the surgical attack upon pulmonary cancer that an analogous type of behavior would be encountered. This assumption has proved to be true. Chart 5 presents additional items in confirmation of the thesis. The forty-eight patients with resection are divided into two groups solely on the basis of whether there was microscopically demonstrable involvement of the regional lymph nodes. The lymph nodes were positive in eighteen cases more than one year after operation. Nine (50 per cent) of these patients survived for one year but only one patient (5.5 per cent) is now living and well for more than a year. Of six patients with positive nodes on whom operation was done more than five years previously, 1 patient survived for five years and is at present alive and well. Thirty patients had negative nodes more than one year later; twenty-one patients (70 per cent) survived for more than a year; and fourteen (46.6 per cent) are now alive and well for more than one year. Of eleven patients with negative nodes more than five years later, four patients (36.3 per cent) survived for five years, and three (27.2 per cent) are alive and well for more than five years.

6. PROGNOSIS IN RELATION TO CELL TYPE (Charts 6A and 6B)

Herein lies the crux of the matter in respect to survival after resection for cancer of the lung. The pathologists, purely on the basis of what they could see in the specimen and in their microscopic slides and without knowledge of the individual clinical problems, have divided these forty-eight cases into four classifications. The specimen in one case was so anaplastic that it could not be classified. That patient died less than one year after the resection (Chart 6*A*). In six patients, after more than a year the diagnosis was undifferentiated carcinoma. One patient is living and apparently well over a year after the resection, but all other patients were dead within a year of the resection. It may be observed that the results in oat cell carcinoma are comparable to those in undifferentiated carcinoma, not one of three patients having survived for over a year after resection. In eight cases (Chart 6*B*) the microscopic diagnosis was adenocarcinoma; five patients (62.5 per cent) survived for a year and two (25 per cent) are now alive and well for more than one year. The longest survival has been three years. Two patients had been operated more than five years previously, but both patients died within three years.

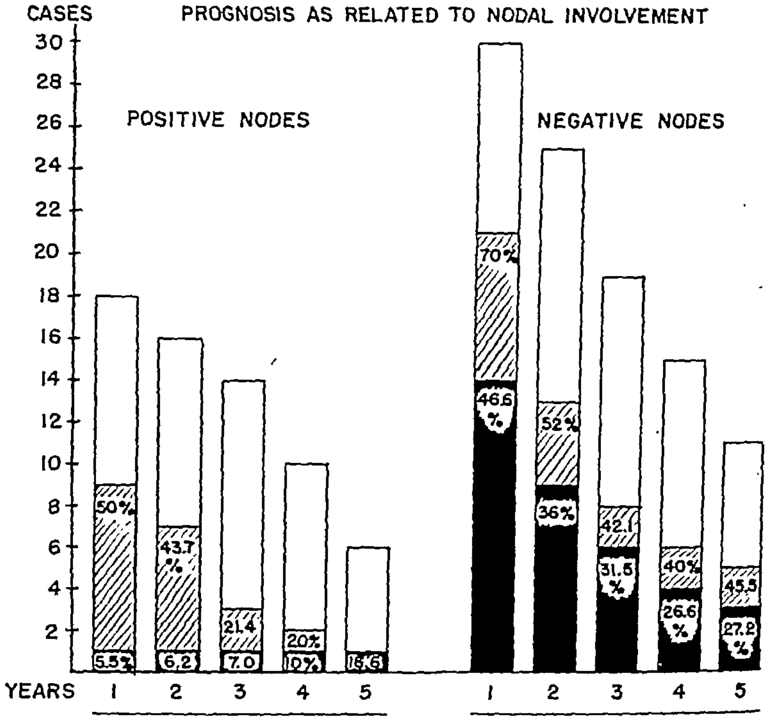

Chart 5.

In Chart 6*B* the thirty cases with a diagnosis of epidermoid carcinoma are also shown. Twenty-four (80 per cent) of these patients survived for more than one year; twelve (40 per cent) are alive and well after more than one year. Of eleven epidermoid cases, after more than five years, four patients (36.3 per cent) are at the present time living and well for more than five years, the longest survivor being alive and well for more than ten years.

If these cases could be multiplied by an experience 100 times as large and if the same general arrangements should be found to persist, one would then have available data of statistical value and significance. Although factually correct, statistical validity is not claimed for the present series because the numbers are too small. These data are presented in a statistical manner in the hope that they accurately reflect trends of behavior in the various types of carcinoma of the lung. When a sufficient number of five-year results for the various classifications of carcinoma of the lung have been published, it should be possible for a statistician of experience to make available to thoracic surgeons a composite analysis of the problem of cancer of the lung of a value and authenticity similar to those studies already established for cancer of the abdominal viscera, the cervix, the rectum, and the breast.

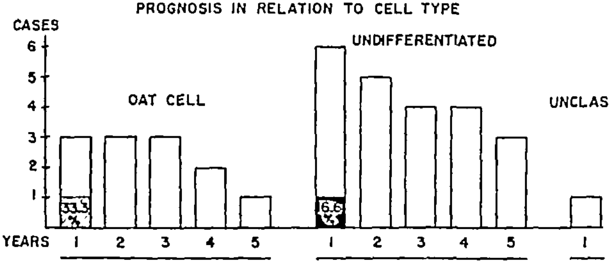

Chart 6A.

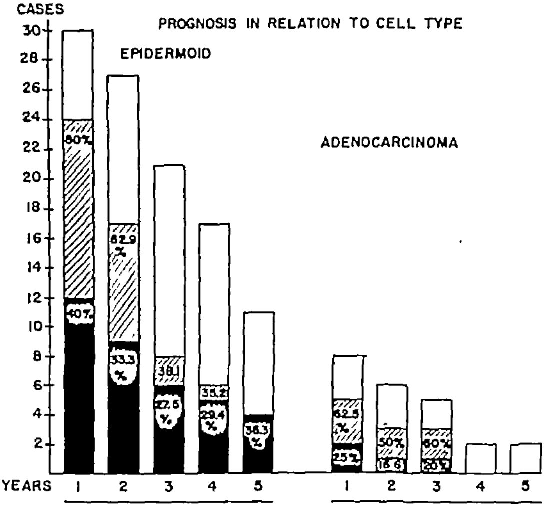

Chart 6B.

7. PROGNOSIS OF EPIDERMOID CARCINOMA IN RESPECT TO BRODERS' SUBGROUPS (Chart 7)

The thirty cases of epidermoid carcinoma were further subdivided by the pathologists into Grades I, II, and III according to Broders' classification.

Only three cases were classified as Grade I, and those three patients are all surviving and well for the period since operation. The longest survivor is now alive and well for four years. No case in this subgroup has been done for as long as five years. Eleven cases were Grade II. Nine (81.8 per cent) of the eleven patients in whom resection was done one year previously survived for a year or more and five (55.5 per cent) are still alive and well. Of six cases in Grade II, after more than five years three patients (50 per cent) are still alive and well. Of sixteen cases of Grade III epidermoid carcinoma, after more than one year, twelve patients (75 per cent) survived more than a year, and four (25 per cent) are still alive and well. Of five cases, after more than five years, 1 patient (20 per cent) remains alive and well. It would seem, therefore, that the subgrouping of epidermoid carcinoma of the lung, as suggested by Broders, has some prognostic value.

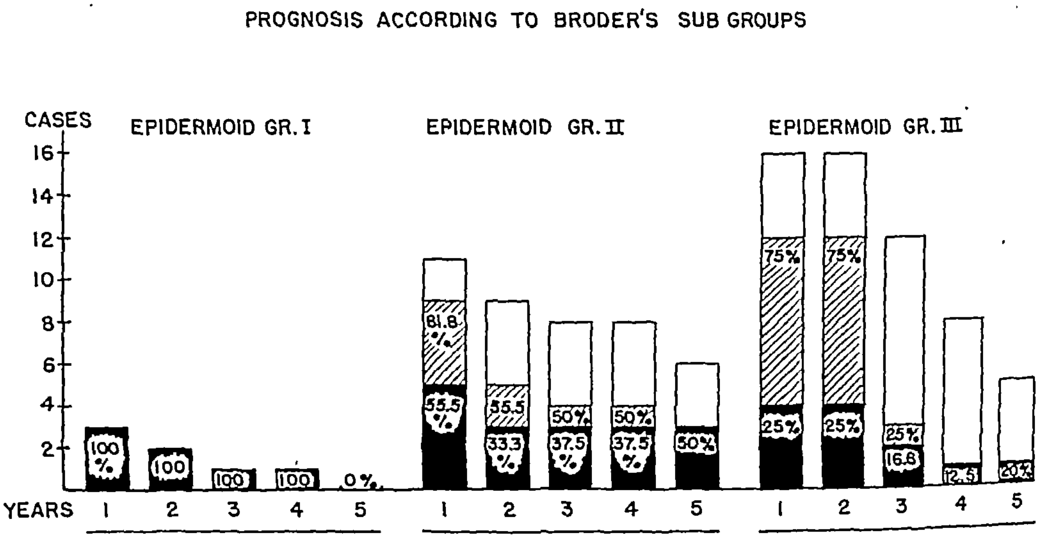

Chart 7.

Like surgery for the treatment of cancer, however, it must be admitted that morphologic study of cancer cells as a means of estimating the prognosis is a method of approximation. Again like the surgeons, the pathologists wish that they had something better to offer. Efforts have been and are being made at refinement by transplants of excised tumor tissue into the corneal cavity of the guinea pig eye. Unfortunately, the infection present in the tumor frequently destroys the transplant. Efforts also are being made along the lines of tissue culture, but this work is still in an experimental stage.

SUMMARY

Factors which may affect length of survival after operative removal of cancer of the lung are analyzed in a series of fifty-six consecutive cases with resection, for the period ending Dec. 31, 1945. These data are correct as of Dec. 31, 1946.

Eight patients (14.3 per cent) died in the hospital. Two deaths occurred in the last thirty-nine resections (5.1 per cent). In the remaining forty-eight cases, seventeen patients have been operated upon for five or more years, of which six (35.2 per cent) survived over five years and four (23.5 per cent) are now living and well for over five years.

Regardless of the duration of symptoms, a patient who has a resection and survives the operative procedure has approximately a 60 per cent chance of surviving for one or more years. Thereafter, the rate of death from recurrence is directly related to the preoperative duration of symptoms for epidermoid carcinoma. In other varieties, the cell type is of greater prognostic significance than the symptoms' duration.

The size of the lesion as judged from a radiographic film is scarcely relevant in estimating prognosis, and even the size of the resected lesion by actual measurement is a poor indication of likely survival time.

With respect to the type of operation done, the survival rate in patients for whom lobectomy was selected has been as good as for patients treated by pneumonectomy.

The absence of demonstrably involved nodes increases threefold a patient's chance of being alive and well five years after resection. For shorter periods, the difference of outlook is even more striking.

The cell type of carcinoma found by microscopic examination is the most important single consideration in estimation of prognosis after a resection. If the growth is undifferentiated or oat cell carcinoma in type, less than a year of life may be expected. Of fifteen patients now living and well beyond one year, twelve had epidermoid carcinoma, two had adenocarcinoma, and one undifferentiated carcinoma. Patients with the epidermoid type of carcinoma have the best prospect of long survival. Broders' method of subgrouping appears to be confirmed as a prognostic aid.

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DISCUSSION

DR. PETER A. HERBUT, Philadelphia, Pa.—The purpose of examining bronchial secretions for neoplastic cells is to arrive at an earlier diagnosis in carcinoma of the lung. The secretions are sent to the laboratory in a collector, and there smears are prepared by the Papainicolaou technique. With these preparations, neoplastic cells are just as pleomorphic as they are in cytologic sections. Accordingly, they may be divided into three main categories:

1. Squamous cell carcinoma, which constitutes about 75 per cent of all primary cancers of the lung.

2. The completely undifferentiated or anaplastic growths which, fortunately, constitute only about 4 per cent of the growths.

3. All the cases between the extremes of No. 1 and 2.

These slides represent some of the cells which are commonly seen. It is virtually impossible to show all the types because they vary so tremendously.

(Slide.) This is the squamous cell carcinoma. One frequently finds large collections of neoplastic cells such as we see here. In the more differentiated growths, these cells still maintain the relatively normal stratification that we see at the periphery and at the lower portion.

The cells have rather indistinct boundaries. Their cytoplasmatic substance here is of an orange color.

(Slide.) In other cases of the squamous carcinomas in which the tumor is more undifferentiated, one again sees large masses of epithelial cells. These cells here, however, are a little bit larger. The borders are still indistinct. The cytoplasm, in contrast to the others, is more bluish-green, and, in areas, of a lighter orange color. The nuclei are large. They are still not extremely hypochromatic. This is a normal epithelial cell of columnar type—we see this tapering end, which is quite characteristic.

(Slide.) Again, in squamous cell carcinomas, we frequently find keratinizing cells such as these, with abundant orange cytoplasm, and intensively hypochromatic nuclei.

(Slide.) Here is a smear of the tumor from the same case. These two cells could be superimposed upon each other. These other cells are neoplastic cells, and they appear different and stain differently than the keratinizing cells.

(Slide.) Once again, from squamous cell carcinomas, a similar type of cell, except this cytoplasm is probably a little more pinkish. In the other slide it was more of a yellowish-orange color. This slide is rather dark, but I think you can see the same type of cell.

(Slide.) Then, also, as far as the squamous cell carcinomas are concerned, we sometimes see these distinct epithelial cells. We see other orange cells, all neoplastic. When one sees such a picture, one can diagnose carcinoma readily.

(Slide.) At the other extreme is the completely undifferentiated type. This is the most difficult to recognize, as you would expect. The cells are round, oval, or elongated. The cytoplasm is almost imperceptible; sometimes there is a scanty amount seen around the nuclei. The nuclei are evenly stained, and sometimes one can see a single or as many as three or four nucleoli within the single nucleus.

These, as I say, constitute only about 4 per cent of the cases. With the knowledge accumulated, our diagnoses, even with these, are more certain than they were before.

(Slide.) In between, of course, one sees many types of neoplastic cells. Here is one which there are two cells coming together. The nucleus, again, is relatively large, occu- s most of the cytoplasm and stain rather lightly. The nucleoli are quite prominent. The cytoplasm is sharply defined, but in other areas it tends to fade out into the rest of the material in the slide.

(Slide.) Here is another type of cell in which the nucleus constitutes practically the entire cell with only scanty cytoplasm along the border.

(Slide.) Here is still another type of cell in which there are four nuclei within a single cell.

(Slide.) And finally, here is a group of three cells in which, again, the cytoplasm is moderate in amount and of a dirty gray color, and the nuclei are deeply stained.

(Slide.) At the time this chart was made, we had 525 preparations, and in those there were 118 cases of proved carcinoma of the lung. Of these 118, the diagnosis was made by the cytologic method in 105, or 89 per cent. Now I might add that some of these patients bronchoscoped three and four times before we found the cells. If there is some question as to whether the cells are positive or not, we ask for repeated bronchoscopic examinations until we can decide one way or another.

The biopsy was positive in fifty-two of the 118 cases, or 44 per cent—less than half of the ones in which we found neoplastic cells in its secretion. However, in addition to these fifty-two cases, there was stenosis or other evidence of bronchial neoplasm, such as distortion, and so forth, in twenty-three.

There were thirty-two cases in which a bronchoscopic examination was completely negative, and in which cells were found in the secretion.

These results we consider as unequivocal. The method is recommended without any reservation.

DR. MICHAEL E. DeBAKEY, New Orleans, La.—The best that we have ever been able to do without the use of this particular method has been a positive diagnosis before exploration in about two-thirds of the cases and in the most recent analysis of our experience this incidence was found to be slightly less than 50 per cent. It is obvious that there is much need for improvement in our diagnostic methods. Our experience with this diagnostic procedure has been limited but we have been so impressed with its value that we now employ it routinely in all cases in which an actual biopsy cannot be obtained.

I should like to show the results of the most recent analysis of our experience with pulmonary malignancy, particularly with regard to the follow-up studies. This first slide shows a break-down of our experience with the total number of 412 cases observed over a period of approximately twelve years. It may be noted that 246 patients (59.7 per cent) were explored and of this number ninety-nine (40 per cent) were found to be nonresectable and 147 (60 per cent) were resectable. Of the 147 patients on whom resection was done, thirty-six (24.5 per cent) died in the hospital and 111 survived the operation. Reduced to simple terms, it may be stated that of every three cases of pulmonary malignancy seen clinically, two will be found operable and only one will prove resectable. Although these figures are somewhat higher than those found in the series collected from the literature, they are in accord with those appearing in the most recent reports which reflect an encouraging trend toward a higher incidence. They are, however, still much too low and emphasize the need for wider recognition of the problem and for earlier diagnosis.

This next slide is a graphic representation of our hospital mortality. Of the total series of 147 cases in which resection was done, the hospital mortality was 24.5 per cent. When these cases are divided into those operated on before and after 1942, the hospital mortality figures for these periods are 40.4 per cent and 10.3 per cent, respectively. While this shows a definite improvement in the mortality rate, it appears still relatively high, but I should like to stress one point in regard to this fact, a point which emphasizes further the statements made by Dr. Gibbon with regard to operability. Approximately one-half of these hospital deaths may be regarded as nonpreventable since they were due to cardiovascular complications, but they represent a risk which must be assumed in pneumonectomy for carcinoma of the lung unless the criteria of operability are so strictly limited that patients in whom they are likely to occur are excluded from surgery and are thus denied their only chance of salvage.

This next slide is especially interesting for it represents the five-year survival rate after resection in the present series of pulmonary malignancy. It may be observed that of the 123 patients operated upon six months or more ago, a little more than one-half survived the six-month period after operation. In this analysis, of course, all deaths, whether in the hospital or after discharge from the hospital, are included. Slightly less than three-fifths of the patients, including those who died in the hospital, died within the first year. After that time, however, the death rate increased much less rapidly and by the end of five years, approximately one-fourth of the patients submitted to resection were still alive. Thus the distribution curve for the survival rate after resection for pulmonary malignancy drops rather rapidly within the first two years after operation, but by the third year it becomes fairly well stabilized and continues almost as a plateau until the fifth year.

This next slide is a graphic representation of the survival rate after resection analyzed from the standpoint of whether the growth was limited to the lung or had extended beyond it by encroachment upon contiguous structures or by regional metastases. As was expected, the survival rate among the patients with localized growths was significantly greater than that for patients with extension, the figures being 42.0 per cent and 6.2 per cent, respectively, at the end of five years. It is particularly interesting that there should have been any patient with extension of the lesion beyond the lung who could have survived five years. This fact emphasizes another point that Dr. Gibbon made concerning criteria for operability.

This final slide summarizes our experience with operability, resectability, and survival rates for carcinoma of the lung. It may be noted that in a given group of twenty-five cases of pulmonary malignancy, about fifteen conditions would meet the criteria of operability and thus be explored; nine, or approximately one-third, would prove resectable; about seven patients, or a fourth of the original number, would survive resection; and only two, or approximately 8 per cent, would survive five years or longer. It is interesting to compare these results with those obtained in the treatment of carcinoma of the stomach, a problem which has received the attention of the profession for a much longer period than that of carcinoma of the lung. Perhaps some gratification may be had from the fact that these results in carcinoma of the lung are somewhat better than those obtained in carcinoma of the stomach.

DR. EVARTS A. GRAHAM, St. Louis, Mo.—I am very glad that it has been possible now to begin to collect statistics over a five-year period on what can be done in the treatment of bronchiogenic carcinoma.

I think that we ought not to be too much encouraged by statistics based on one- or two-year survival periods. We must remember that bronchiogenic carcinoma, so far as we know, does not differ materially from other types of carcinoma that we know about. In other words, this disease is included in the all-embracing field of cancer.

We have some pretty well-established facts about cancer in general, one of which is that any statistics based on periods of less than five years are likely to be misleading. That, of course, does not prevent us from talking hopefully and optimistically about our results over a one-year or two-year period, but I question very much whether conclusions arrived at on the basis of patients who have survived one year or two years are going to be very important after a five-year period has elapsed.

Now you may wonder what I am getting at. Well, I was much interested in the figures which Dr. Aufses presented, but do not we know in regard to cancer in general that the most likely period of recurrence, if you will, is in the first two years after the operation? What reason is there to think that bronchiogenic carcinoma is any different in that respect? Why is it necessary to emphasize the fact that a patient who survives a two-year period after an operation for bronchiogenic carcinoma is less likely to die of so-called recurrence of his disease than if he has just survived his operation and we were waiting for the first two-year period to go by?

Again, the question about partial resection of the organ enters into this picture. It is quite possible that because of the sharp differentiation between portions of the lung, as shown anatomically by different lobes, we may find that in cases classified as Dr. Aufses classified them, it is a reasonably safe procedure to perform an elective lobectomy rather than a pneumonectomy, particularly in consideration of the mortality of lobectomy versus pneumonectomy.

After all, of course, what we are all striving for is to have as many patients alive as possible after five years. Therefore, operative mortality is something that must be taken into consideration, naturally.

However, I would like to say again something that certainly should be known, I think, to everybody in this room, and that is that if we compare bronchiogenic carcinoma with an organ that has been worked over now for fifty years, namely, the breast, we have a structure in the breast which has lobes in it, perhaps not so sharply distinguished from each other as those in the lung. We know unequivocally that many women with cancer of the breast have recovered simply from a local excision of the cancer, a lobectomy, if you will, of the cancerous portion of the breast. All you need to do is look up the old literature, and, for that matter, look up some of the more recent literature.

We know, also, that many women have survived with the simple removal of the breast itself, by simple mammectomy, but we know still better that by far the best results that have been obtained in thousands and thousands of cases now on record have been obtained by the so-called radical operation, which means the removal of the axillary lymphatics, the fascia underlying the breast, and the pectoral muscles.

I think anybody would be courageous to bring up now, at this time, a plea for a simple excision of the carcinoma, or even a simple mammectomy in the presence of carcinoma.

The point was made that in cases in which there is regional gland involvement, pneumonectomy should be done. I do not know any way to tell whether or not the regional lymph glands have been involved. Certainly one sometimes finds that the glands are enlarged and hard, but in many other instances one can tell only by a microscopic examination of the lymph glands that are removed, and I don't know of any way by which the surgeon, in the course of the operation, can tell merely by an inspection of those glands, or palpation of them, whether or not they are involved with cancer.

There is no doubt, however, about the statement which Dr. Aufses made that in the tumors which are situated away from the hilum, the lymph glands are less likely to be involved than in those cases in which the tumor is situated in the major bronchi, close to the hilum.

I think it is very fortunate that there are some who are willing to try out lobectomy as a cure for bronchiogenic carcinoma in an experimental manner. I hope they will continue to do so. I hope that in another five years we can compare those figures with the figures which will be obtained on the basis of a total pneumonectomy for carcinoma.

I do not want to be misunderstood. I am not saying that a lobectomy should never be done in a bronchiogenic carcinoma, having done it myself. I cannot help thinking, however, by comparison with what we know about cancer in other parts of the body, that, provided the operative mortality for pneumonectomy does not bring the total mortality to too high a figure, more patients will have survived the five-year period, not a two-year period or a one-year period, after total pneumonectomy than after lobectomy, but here again, my guess about this is no better than that of anybody else.

I am delighted that we have this array of papers this morning, presenting figures over a considerable period of time.

On Friday afternoon I am going to present some patients who have kindly consented to come back after five years' survival of pneumonectomy, who present different phases of this question, pathologically as well as otherwise, and I should prefer to enter into other features of this discussion at that time.

I may say here, however, that of 53 patients who had pneumonectomies prior to 1942, in other words, more than five years ago, 15 are alive and well. This is a five-year survival rate of 28 per cent. In 6 of the 15 cases regional lymph glands were invaded. The first patient to have a successful pneumonectomy for cancer (squamous carcinoma) is living and well in the fifteenth year since his operation. He has consented to return here for demonstration next Friday.

DR. JOHN W. STRIEDER, Boston, Mass.—I would like to show briefly what our experience at the Boston City Hospital Thoracic Service has been with smears of bronchial aspirations in cases of suspected or proved bronchiogenic cancer.

(Slide.) Of 147 patients from whom over 800 smears were made, there were 40 cases of bronchiogenic carcinoma. Thirty-four of these carcinomas had a positive smear for tumor cells, which is 85 per cent positive, or, stated otherwise, there was a 15 per cent error in diagnosis.

(Slide.) In sixteen of the cases the only proof was by operation or post-mortem examination. The smear was positive, however, so that in 40 per cent of the cases, the smear was the sole positive diagnostic evidence other than the clinical evidence.

There were three so-called false positives. One proved to be a bronchial adenoma.

Another was a case showing localized effusion, with left lower lobe atelectasis, which, at operation, proved to be tuberculous by biopsy of pleural granulation tissue.

The third case was a woman who had chronic blood spitting, and smears from the bronchus were read first as positive for tumor cells. The local findings were not such that operation was justified, and repeat smears later were negative. Subsequent bronchoscopic evidence was that of clearing.

In the over-all picture, there were three false positives, or three mistakes out of 147 patients. The error is a little over 2 per cent.

DR. ALFRED GOLDMAN, Los Angeles, Calif.—I wish to comment very briefly upon an approach that I have used for the past ten months, which is somewhat different from the usual Rienhoff approach for resection of the lung.

During this period of time I resected fifteen tumors of the lung, two of which were adenoma, and thirteen of which were done through this incision.

(Slide.) This incision was evolved because I wanted to get away from having the patient with his good lung down in a position which compromises his respiration while one might be operating on him. This is the position that we use at the Birmingham Veterans' Hospital and at Cedars of Lebanon, Los Angeles.

The incision begins at the second costal cartilage, goes down to the fifth or sixth interspace, and follows that interspace to the mid- or posterior axillary line.

(Slide.) After cutting the pectoral muscle, the cartilages underlying, one-half to three-quarters of an inch each, are resected. This shows the resected cartilages. Usually three cartilages are transected.

(Slide.) This slide shows the outfolding of the ribs, which have been freed after going through the intercostal space and opening the pleura throughout the length of the intercostal space into the axilla and anteriorly resecting through the bed of the cartilages lateral to the internal mammary vessels. The outfolded third, fourth, and fifth ribs are shown here.

One dissects with the chest open, the interspace all the way down to within about one inch of the transverse process.

This is the artist's drawing depicting a wide exposure, which has always been so well advised by Dr. Harold Brunn, who has used this principle both in chest and in general surgery.

(Slide.) This shows a view of the chest with the lung removed, the vessels ligated, and the bronchus closed. Through this incision I have also ligated the pulmonary vessels in the pericardium.

(Slide.) This shows the method of closure subperiosteally, using a double No. 1 chromic suture to approximate the ribs, and interrupted 0 chromic to approximate the pectoral muscle, not doing anything to the cartilages themselves.

By having a patient on the back, one can do extensive mediastinal dissection, and a prolonged operation, with less danger of producing atalectasis or pneumonia in the contralateral lung, and in this position one may have the bronchus open after transection and suck it out, thereby further obviating aspiration of secretions into the contralateral lung.

DR. JEROME R. HEAD, Chicago, Ill.—Dr. Graham has stated that the aim of surgery for bronchiogenic carcinoma should be to have as many patients as possible alive at the end of a five-year period. With this statement I disagree, because on the basis of it Dr. Graham has recommended that pneumonectomy be always preferred to lobectomy for bronchiogenic carcinoma.

In patients in the older age groups, pneumonectomy is a crippling operation. They live, but do not live happily, and very few of them can follow a gainful occupation. They are only half alive and only half functioning. Lobectomy is a much less crippling operation, and following it most patients retain a good vital capacity and are able to function normally. For this reason I feel that in this group of older people, lobectomy, when it can be done, is preferable to pneumonectomy. I am sure that if the choice were up to me I would rather accept a 10 per cent chance of survival by lobectomy than a fifteen per cent chance from pneumonectomy.

We must balance the good which we do for people who have cancer against the harm which we may do to those whom we explore for cancer but who prove eventually to have some other disease. It is absolutely essential that pneumonectomy be avoided for noncancerous conditions which might recover from some simpler treatment. Even at operation itself it is extremely difficult to say for certain whether or not cancer is present. It is often necessary to remove the diseased lobe before the diagnosis can be certainly established. As I have said before, removal of a lobe is not dangerous or disabling, while removal of a whole lung is infinitely more serious.

The papers presented this morning on examination of the cells in the sputum gave promise that this method will be a great aid in preoperative diagnosis of cancer of the lung. It is, however, improbable that it will be so accurate that one can rely entirely on sputum findings. When other symptoms and signs suggest cancer, exploration will still probably be indicated and one will probably not be justified in removing a lung simply because cancer cells are supposed to have been found in the sputum.

In this diagnosis, a 2 per cent error in either direction is still an appreciable error, and to remove even two lungs out of 100 which do not need removal is a risk which cannot and should not be taken.

DR. EDWARD E. AVERY, Hines, Ill.—I would like to add to the statistical series, fifty cases of bronchiogenic carcinoma which were resected by Dr. Jerome Head at Hines Hospital.

Under Group 1, the hilus tumors, twenty-nine were resected and 4 patients are living for a period of more than two years.

Of Group 2, peripheral circumscribed tumors, fourteen were resected; five patients are now living.

Of Group 3, peripheral invasive tumors, seven were resected and all patients are dead.

We have been unable to correlate the cell type with the survival of our nine living patients. Five of them had undifferentiated carcinoma.

Broders said that tumors are like a chain, only as strong as the weakest link, and the malignancy depends upon the most anaplastic cell in a tumor; therefore, the complete tumor must be sectioned, and all sections reviewed.

We had an interesting patient which we were about to chalk up as a five-year cure. He returned in four years and eight months with recurrence in the opposite lung, and his original tumor was an undifferentiated carcinoma.

DR. JOHN H. GIBBON, JR., Philadelphia, Pa.—I must say that I disagree with my good friend, Jerry Head, and firmly agree with Dr. Graham. I think that the proper operation in dealing with carcinoma of the lung is pneumonectomy. The one case in which we did a partial resection was erroneously diagnosed a tuberculoma at the time of operation.

I agree with Dr. Head that it is extremely important, if possible, to make the diagnosis before exploration. In our thirty-one explored cases there were four in which we could not make a positive diagnosis before operation. It also may be quite difficult at the time of operation to be sure that you are dealing with a malignant tumor.

So far we have not yet removed a lung because of a mistaken diagnosis of cancer. I quite agree with Dr. Head that you must be very sure of the diagnosis before performing a pneumonectomy.

DR. PETER A. HERBUT, Philadelphia, Pa.—As far as the positive diagnoses are concerned, our results in the last sixty cases are even better than the ones we showed in the over-all picture, for in these we missed only three cases which brings the total to about 95 per cent.

We have not made any false positive diagnoses in the last year. Prior to that time I called two cases carcinoma that were not. In rechecking each of these I would now call them negative.

There were two other cases that aroused a suspicion of carcinoma, but I did not give an outright diagnosis. In both of these there was a single clump of epithelial cells of the stratified-squamous type, which represented a metaplasia. Each patient had an abscess of the lung. We have seen several such cases since then, and have not misinterpreted any of them.

Tuberculosis offers us no difficulty. As a rule we can pick out such cases from examining the smears for they have a distinct cytological pattern.

I would like to add just one more thing. In many of the cases, there are no secretions in the bronchi whatsoever at the time of bronchoscopic examination. In these, Dr. Clerf has recently been instilling 2 to 5 c.c. of saline into the segment suspected of containing the cancer, reaspirating the washings and sending them to the laboratory. Since Christmas, we have made a positive diagnosis in nine such cases where there were no secretions available otherwise.

DR. HAROLD NEUHOF, New York, N. Y.—Concerning the question of late results in cancer of the lung, reference has been made to the fact that there is little to be judged by a two-year result. I am sure that Dr. Adams will speak for himself, but it is of interest to note that we each separately arrived at the same conclusion, and certainly not in any planned way. Indeed, we were surprised to learn that there was a sharp line of cleavage represented by the two-year period after operation.

It is therefore only fair to emphasize the fact that after two years, there is this almost complete drop—all the way up to whatever number of years we have reported—in the incidence of recurrence or metastasis in these cases, and it would seem that rather than to assume this to be accidental to consider it due to the peculiar feature of cancer of the lung, under a certain set of circumstances.

I refer specifically, of course, to the question of regional node involvement. Mention has been made of the analogy which one could draw, let us say, between cancer of the breast and that of the lung, but we believe the evidence is that this analogy cannot be made, by virtue of the fact that, according to our observations, a substantial proportion of patients with cancer of the lung, chiefly those with circumscribed cancer of the lung, are patients in whom there is no regional node involvement at the time of operation.

The recognition of the absence of regional node involvement is not, of course, on the basis of inspection as has been suggested but in those cases in which there are nodes as in instances in which there is a circumscribed cancer of the lung for which lobectomy is proposed, frozen sections are taken of any nodes that appear to be involved and a lobectomy is not proceeded with unless there is no known regional node involvement.

There is one aspect of our observations to which I should like to call attention, and that is what appears to be something in the nature of an emergency situation when the diagnosis of cancer of the lung is made, and more particularly, perhaps, in cases of known slowly growing tumors. For example. Some little time ago Dr. Aufses operated upon a man who had a known slowly growing tumor without any additional symptoms. The operation was deferred for some time merely because it was a tumor which grew so slowly. This was a circumscribed tumor, and at the time of the exploratory operation, there was extensive involvement by carcinoma of the pleura, undoubtedly a very recent development.

More recently there was a patient, a man of 60 years, who had a slowly growing tumor in the left upper lobe, on whom operation was deferred because he wished to attend the wedding of his daughter, about three weeks from the time the diagnosis was made and the decision made to operate. Two and one-half weeks after the time he was seen, he complained of some pain in the right chest opposite to the side of the tumor. A film then revealed a destruction of one rib due to a blood-borne metastasis.

It has been a surprise to us to have found that a substantial proportion of patients with or without regional node involvement may develop blood-borne metastasis virtually any time during the period of tumor growth. Thus it would seem to us to make imperative an emergency approach to the attack by surgery when the diagnosis has been established and the case deemed favorable for surgical eradication.

THE EFFECT OF PULMONARY INFLATION AND DEFLATION UPON THE CIRCULATION

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In previous articles we have described several methods of observing the effect of artificial respiration upon the circulation in animals.[1-3] This present paper is a critical review of all of the methods which we have used and a summary of the observations related to this work.

The basic method of determining the circulatory effects of artificial respiration is the intravascular injection of tracer substances and the observation of the movement of these tracer substances during the application of some form of artificial respiration.

The tracer substances which we have used are radioactive sodium, fluorescein, and oxygen. Another method which we have not yet reported is the use of Diodrast. This is injected intravascularly and its movement is observed under the fluoroscopic screen or by means of x-ray films.

Any cardiac activity is a variable factor in circulatory movement. Any active respiration is also a variable factor in circulatory movement. In order to remove as many variables as possible and to disassociate cardiac activity and respiratory movement, the experiments were carried out on animals a short time after they had succumbed to asphyxia.

The efficiency of artificial respiration varies with each method. The manual methods are inefficient, inconstant, and uncontrollable. For these reasons they were not used. The mechanical methods are more efficient, and can be controlled by a constant pressure. For these reasons, the mechanical methods were used. All methods of artificial respiration produce pulmonary ventilation in one of three ways: (1) inflation of the lungs; (2) deflation of the lungs; or (3) a combination of inflation and deflation of the lungs. We used all three methods to determine their relative effects upon the circulation.

TECHNICAL PROCEDURE

All of the experiments were performed on dogs. The animal was anesthetized by intraperitoneal nembutal. One femoral artery and one femoral vein were exposed, cannulized, and the cannulas left in situ. An endotracheal tube with occlusion cuff was then inserted and the cuff inflated to make a leak-proof and closed connection with the lungs. Arterial and venous blood specimens were now collected for control comparisons. To prevent the intravascular clotting of blood which occurs soon after death, 2 to 5 c.c. of heparin were injected into the femoral vein. About five to ten minutes after the heparin was injected, the endotracheal tube was completely clamped off and the animal was allowed to succumb by obstructive asphyxia.

Clinical death took place in about eight to ten minutes but to insure complete (biological) death with no subsequent cardiac activity, the endotracheal tube remained clamped off for

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From the Thoracic Surgical Service of the New York Medical College, Flower and Fifth Avenue Hospitals.

Read at Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

an additional twenty to thirty minutes. At the end of this time the endotracheal tube was unclamped and connected to a resuscitator. The resuscitators used a positive pressure of plus 14 mm. of mercury and a negative pressure of minus 9 mm. of mercury. The rate was set at 16 to 20 respirations per minute. The tracer substance was now injected into the femoral vein or artery and the resuscitative procedure was started and continued for forty-five to sixty minutes. To counteract any possible effect of gravity in causing diffusion of the tracer substance toward the heart, the animal was placed on an incline plane with the head elevated about 20 degrees.

In the experiments where radioactive isotopes were used as a tracer, about 2 c.c. of normal saline containing 50 to 60 microcuries of radioactive sodium, were injected into a femoral vein or artery. The Geiger-Mueller counter was placed against the neck of the dog in proximity to the carotid artery, and the resuscitative procedure started. During this period the counts per minute registered by the counter were recorded and plotted on a curve. At the end of the resuscitative time, samples of blood were taken from the femoral vein and artery of the opposite leg, from the right and left side of the heart, the jugular vein and carotid artery. Measurements were made of the radioactive sodium contained per cubic centimeter of each of these samples.

Experiments were carried out with the following combination of conditions (Fig. 1):

Intravenous sodium with alternating inflation and deflation of the lungs; inflation alone; or deflation alone.

Intra-arterial sodium with alternating inflation and deflation of the lungs.

Controls, with intravenous sodium with heparin and no resuscitative procedure; or alternating inflation and deflation with no heparin.

In the experiments where oxygen was used as the tracer substance, the animal was prepared in the same manner as described above. A sample of blood was removed from the femoral vein and artery for analysis of its oxygen content or tension. Again the heparin was injected and the animal was allowed to succumb to obstructive asphyxia. About twenty to thirty minutes after death another sample of blood was removed from the femoral artery and vein and analyzed for its oxygen tension. The endotracheal tube was connected to a resuscitator and one of the resuscitative procedures was begun and continued for forty-five to sixty minutes. At approximately five-minute intervals additional specimens of blood were taken from the femoral vein and artery for analysis of the oxygen tension.

Experiments were done with inflation of the lungs; with deflation and with a combination of inflation alternating with deflation of the lungs (Figs. 2 to 7).

In those experiments where fluorescein was used as the tracer substance, the animal was prepared in the same manner as described above. About twenty to thirty minutes after the dog had succumbed to obstructive asphyxia, 2 c.c. of a fluorescein solution were injected into the femoral vein or artery and the resuscitative procedure was started.

Inflation of the lungs or deflation or a combination of the two was continued for about thirty to sixty minutes, during which time frequent observations were made with an ultraviolet light for evidence of fluorescein in the skin or mucous membranes of the oral cavity (Figs. 8 to 10). Fluorescein is a substance having the property of emitting a very intense golden-green light when it is illuminated by ultraviolet light and is thus grossly visible.

RESULTS

When the radioactive sodium and Geiger-Mueller counter were used our observations showed that the inflation and deflation of the lungs produced a forward movement of the blood, which was circulated in the normal direction; a tracer substance injected into a peripheral vein was carried to the right heart, then to the lungs, to the left heart, to the arteries, and back to the veins again. This circulatory movement, without benefit of cardiac activity, appears to be due to the filling and emptying of the pulmonary capillaries produced by the artificial respiration. While this circulatory movement is in no way comparable in volume or rate to the movement produced by cardiac activity, it is, nevertheless, a definite circulatory movement and in the normal direction (Fig. 1).

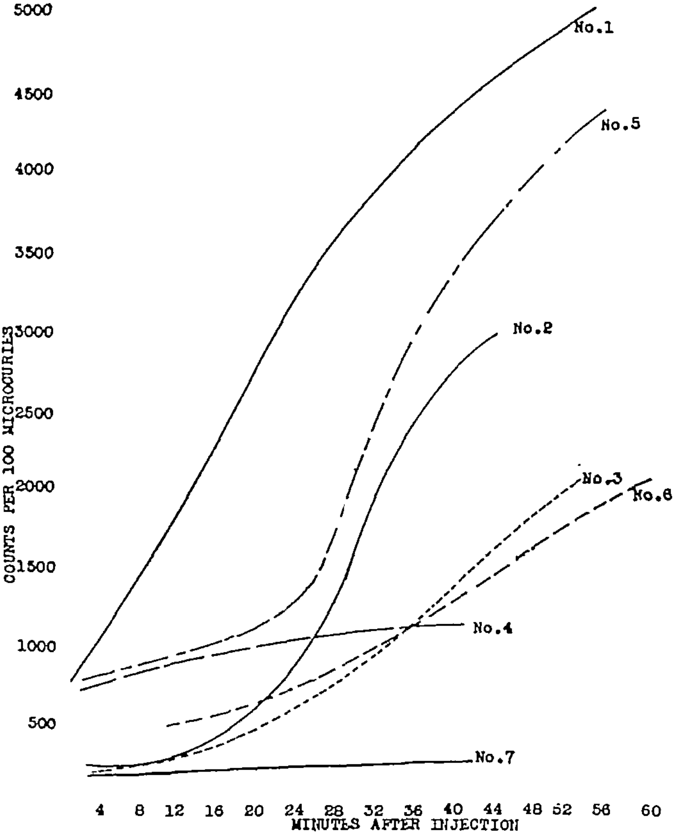

Fig. 1.—No. 1, Heparin; intravenous sodium; double action resuscitator.
No. 2, Heparin; intravenous sodium; double action resuscitator.
No. 3, Heparin; intra-arterial sodium; double action resuscitator.
No. 4, No heparin; intravenous sodium; double action resuscitator.
No. 5, Heparin; intravenous sodium; suction only.
No. 6, Heparin; intravenous sodium; pressure only.
No. 7, Control; heparin; intravenous sodium; no resuscitator.
(Courtesy of *Surg., Gynec. & Obst.*)

The intra-arterial injection of the tracer required a longer time to reach the counter by reason of the fact that it had to pass from artery to capillary before getting to the veins.

A control in which no resuscitation was used showed that the tracer substance remained where it was injected without diffusion. A control in which no heparin was used showed the intravascular clotting of the blood which prevented any circulatory movement (Fig. 1, no. 7).

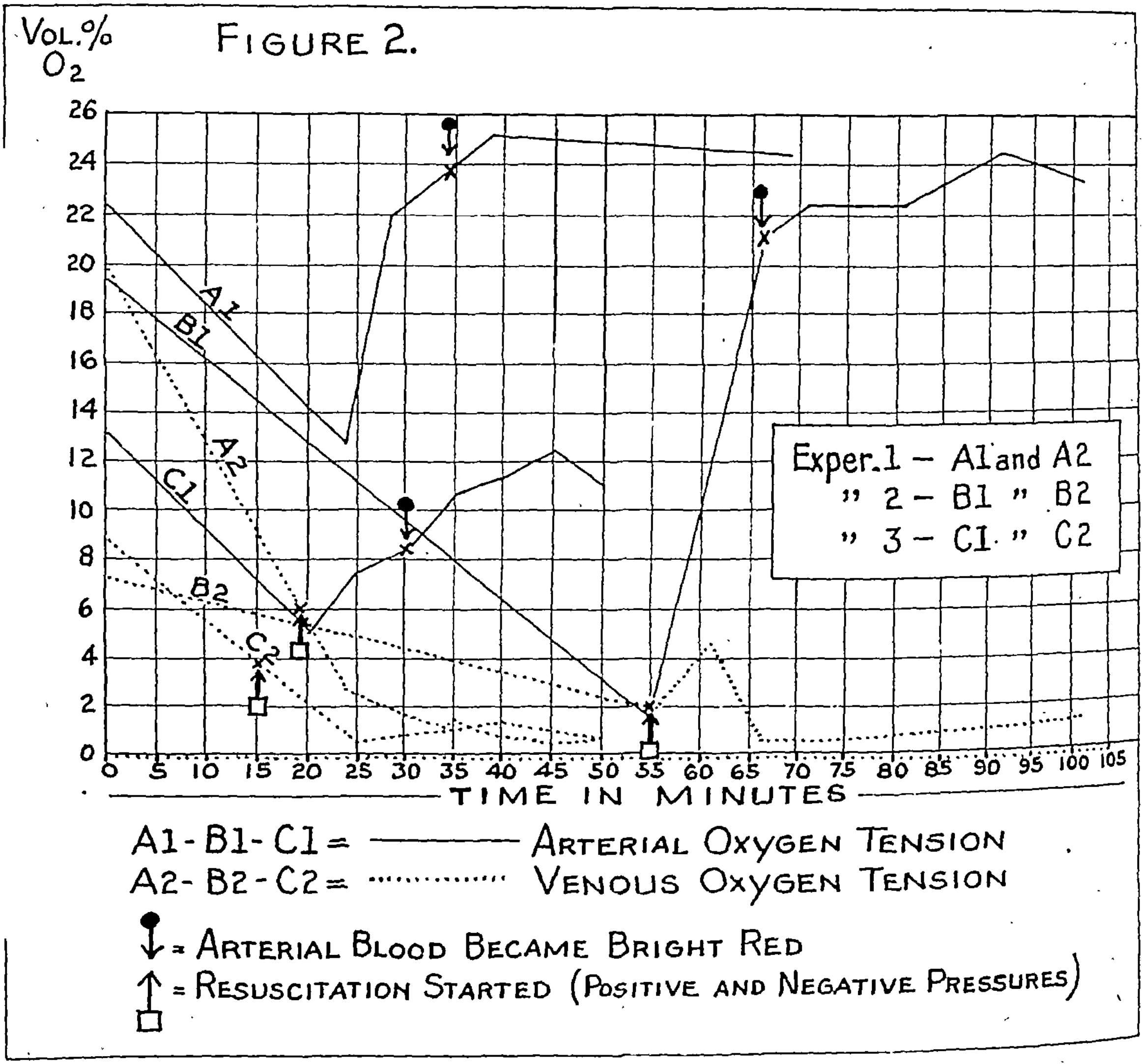

Fig. 2.—Alternating positive and negative pressure with 100 per cent oxygen used on three dogs. The vertical line shows the blood oxygen tension in volume per cent. The horizontal line indicates the time in minutes. (Courtesy of *Surg., Gyneo. & Obst.*)

Experiment 1: The arterial blood oxygen tension has regained its preasphyxia level in approximately ten minutes after resuscitation was started.

Experiment 2: The arterial blood oxygen tension rose rapidly and has passed its preasphyxia level in eleven minutes after resuscitation was started.

Experiment 3: There was a rapid rise of the arterial blood oxygen tension in the first ten minutes of resuscitation followed by a more gradual rise. The blood became bright red in fifteen minutes.

When the fluorescein was used our observations also showed that the inflation and deflation of the lungs produced a forward movement of the blood which was circulated in a normal direction and the tracer substance was carried from vein to right heart, to lungs, to left heart, to artery, and back to vein again. Autopsies showed the tracer substances in the coronary vessels as well as in the vessels of the brain. The shortest time required for this tracer to be moved from the femoral vein to the oral mucous membrane was ten minutes (Fig. 8).

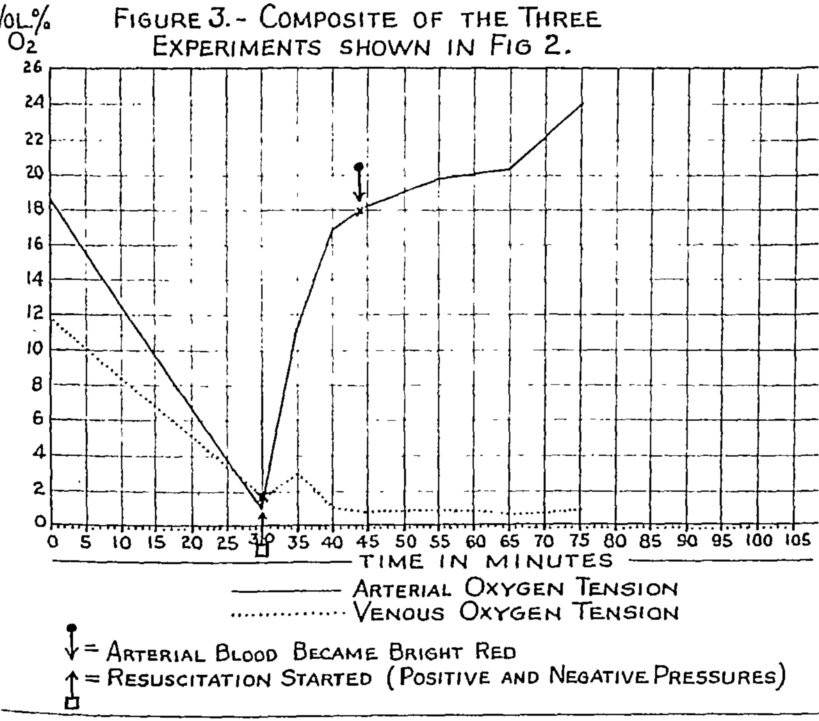

Fig. 3.—This is a composite of the three experiments in Fig. 2. The oxygen tension of the arterial blood rose rapidly in the first fifteen minutes of resuscitation, continued to rise, and at forty-five minutes was much higher than the preasphyxia level. The arterial blood became bright red in fourteen minutes. This charted curve is superior to those shown in Figs. 5 and 7 and indicates a more efficient movement (volume and speed) of the blood column by this method. (Courtesy of *Surg., Gynec. & Obst.*)

A control in which no resuscitation was used showed only slight local diffusion of the tracer. Another control in which no heparin was used showed intravascular clotting of the blood with only slight local movement of the tracer substance.

When oxygen was used as the tracer substance, the only place where the blood cells could become oxygenated was in the pulmonary capillaries. The only way these oxygenated cells can be transported from the pulmonary capillaries to other parts of the body is through the vascular system.

The method of frequent analysis of the blood taken from the femoral vessels while the lungs were inflated and deflated with oxygen made it possible to detect any change in the oxygen tension of the peripheral blood. After asphyxia, the appearance and gradual increase of oxygenated cells in the femoral artery constitutes definite proof of the forward movement of the blood from the pulmonary capillaries to the femoral artery. As the heart is no longer beating or active this forward movement of the blood is produced by the mechanical inflation and deflation of the lungs acting upon the pulmonary capillaries.

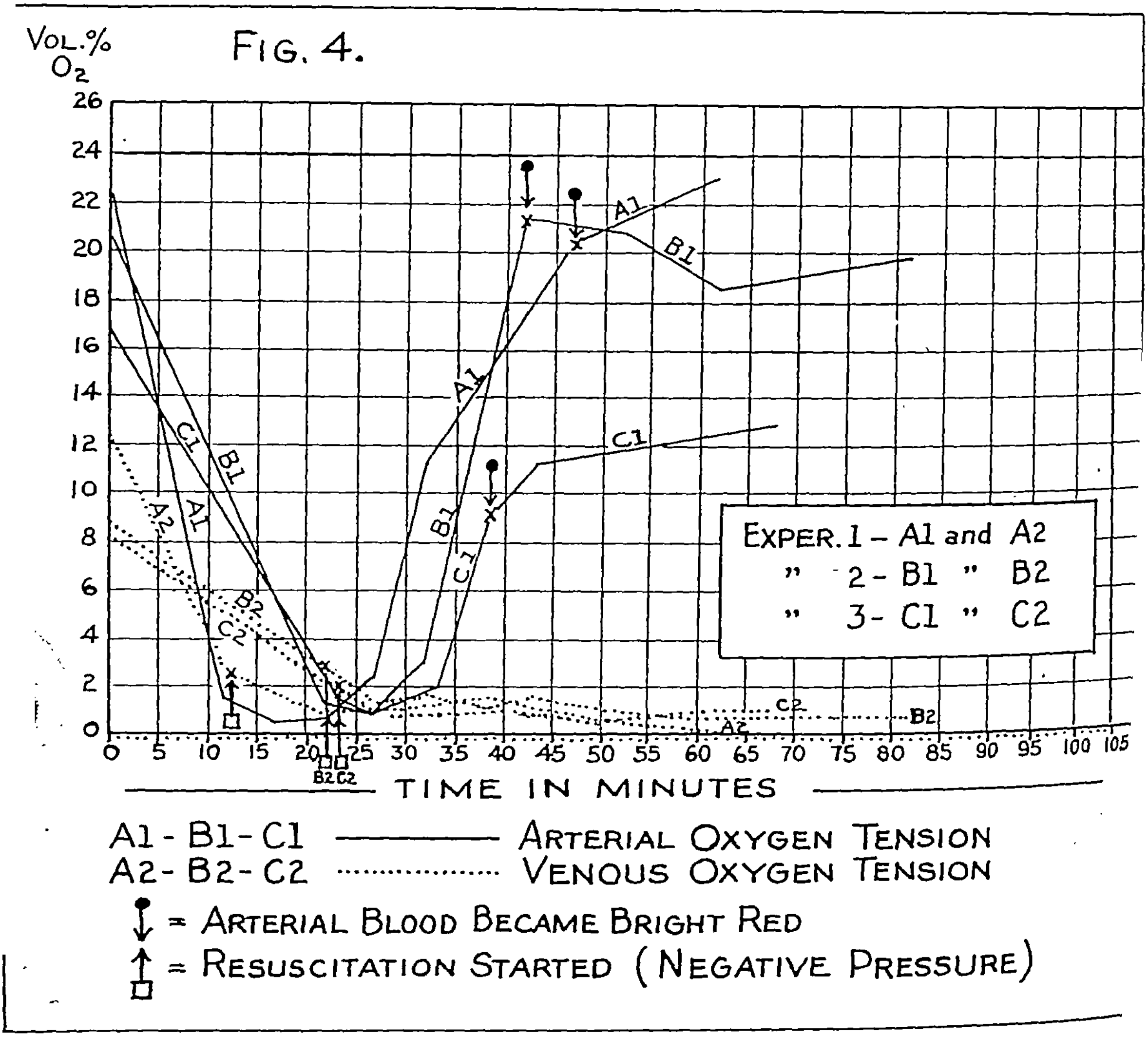

Fig. 4.—Negative pressures and release with 60 per cent oxygen was used in three experiments. (Courtesy of *Surg., Gynec. & Obst.*)

Experiment 1: The arterial blood oxygen tension was lowered at first and later began to climb. It gained its preasphyxia level in approximately fifty minutes after resuscitation was started.

Experiment 2: The arterial blood oxygen tension reached its preasphyxia level in approximately twenty minutes after resuscitation was started.

Experiment 3: The arterial blood oxygen tension did not reach its preasphyxia level in forty-five minutes, although the blood became bright red in nine minutes.

In these experiments, the shortest time in which the oxygen tension of the blood in the femoral artery had regained its normal preasphyxia level (Fig. 2) was ten minutes after artificial respiration was begun.

A control in which no resuscitator was used showed no change in the femoral artery blood oxygen tension. Another control in which no heparin was used showed intravascular clotting and no change in the blood oxygen tension.

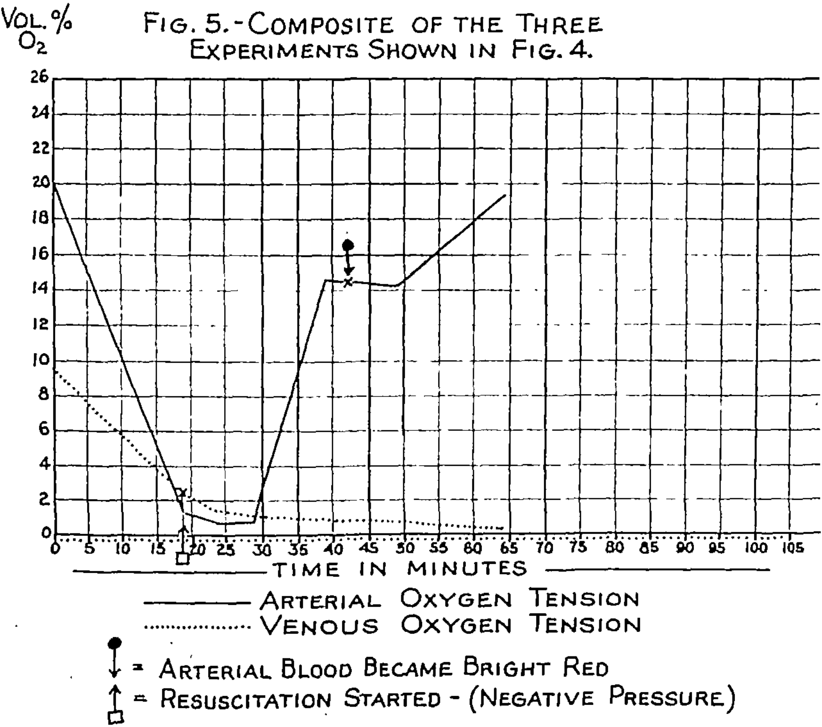

Fig. 5.—This is a composite of the three experiments in Fig. 4. The arterial blood oxygen tension fell at first and later rose, but required approximately forty-five minutes to regain the preasphyxia level. This curve is inferior to that of Fig. 3, where positive and negative pressures were used. (Courtesy of *Surg., Gynec. & Obst.*)

DISCUSSION

The mechanical inflation and deflation of the lungs produce a dilatation and compression of the pulmonary capillaries which results in a movement of the blood contained in these capillaries. This movement is in a normal direction and completes the circuit from lungs to left heart to arteries to veins to right heart and back to the lungs again. This movement can be determined by the use of the three tracer substances just described. It is not likely that the volume or rate of such a blood movement alone could be life sustaining. However, in resuscitation such a blood movement might be of value in stimulating cardiac activity and protecting the brain cells from prolonged anoxia.

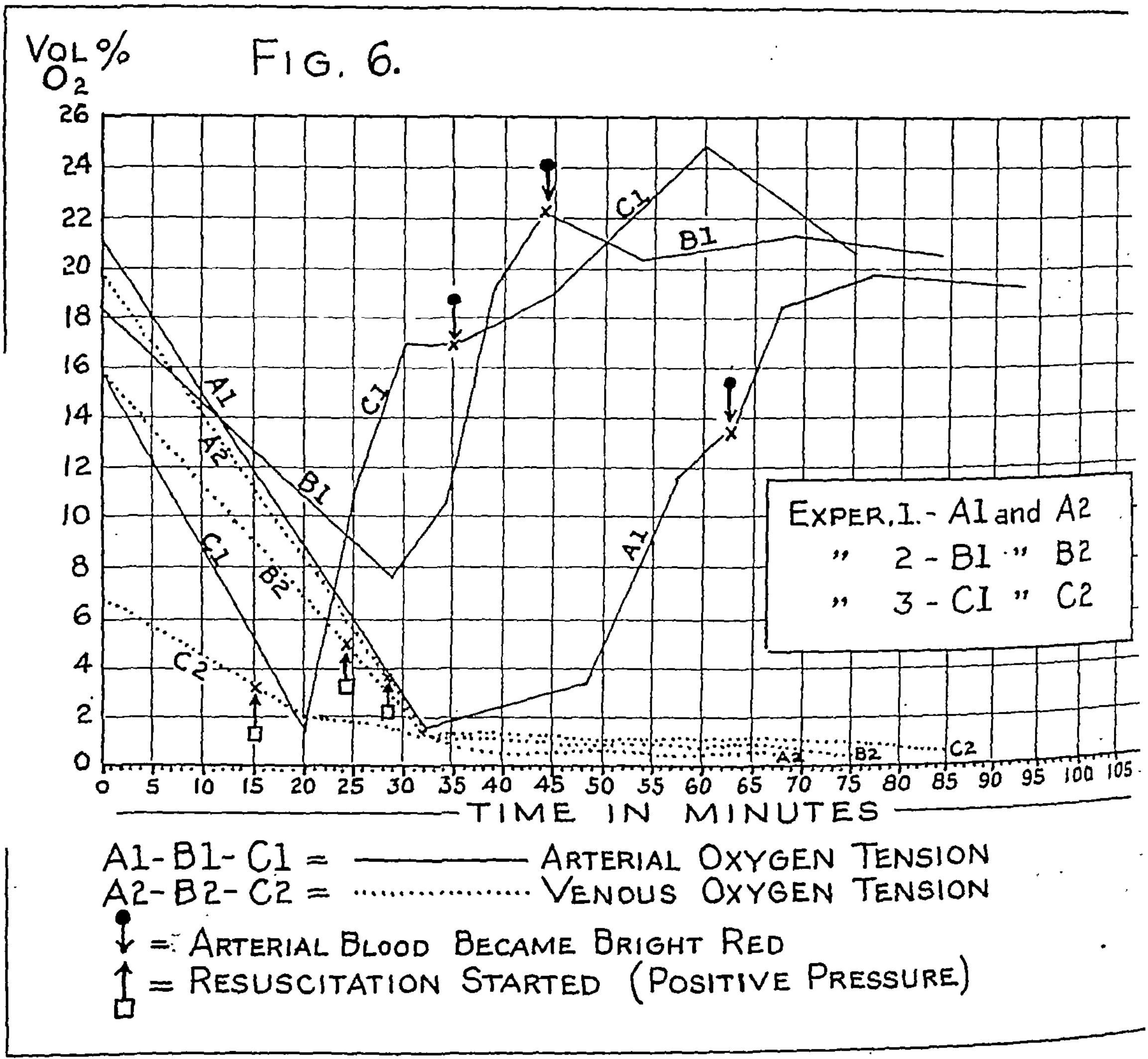

Fig. 6.—Positive pressures and release with 100 per cent oxygen was used in three experiments. (Courtesy of *Surg., Gynec. & Obst.*)

Experiment 1: The arterial oxygen tension did not reach its preasphyxia level in sixty-five minutes. The blood became bright red in thirty-five minutes.

Experiment 2: The arterial blood oxygen tension reached the preasphyxia level in about twenty minutes.

Experiment 3: The arterial blood oxygen tension rose rapidly and reached the preasphyxia level in approximately fifteen minutes.

The type of resuscitation appears to make a considerable difference in the speed and volume of the blood movement. A study of the charts and tables shows that in all three groups of experiments the use of positive pressure inflation alternating with (suction) negative pressure deflation of the lungs was on the average about 100 per cent more efficient in the rate and volume of blood movement than was either positive pressure alone or negative pressure alone (Figs. 1, 3, 5, and 7 to 10). This fact is interesting since many authors on resuscitation feel that the addition of negative pressure (suction) deflation in resuscitation is either unnecessary, or harmful, or has no value.

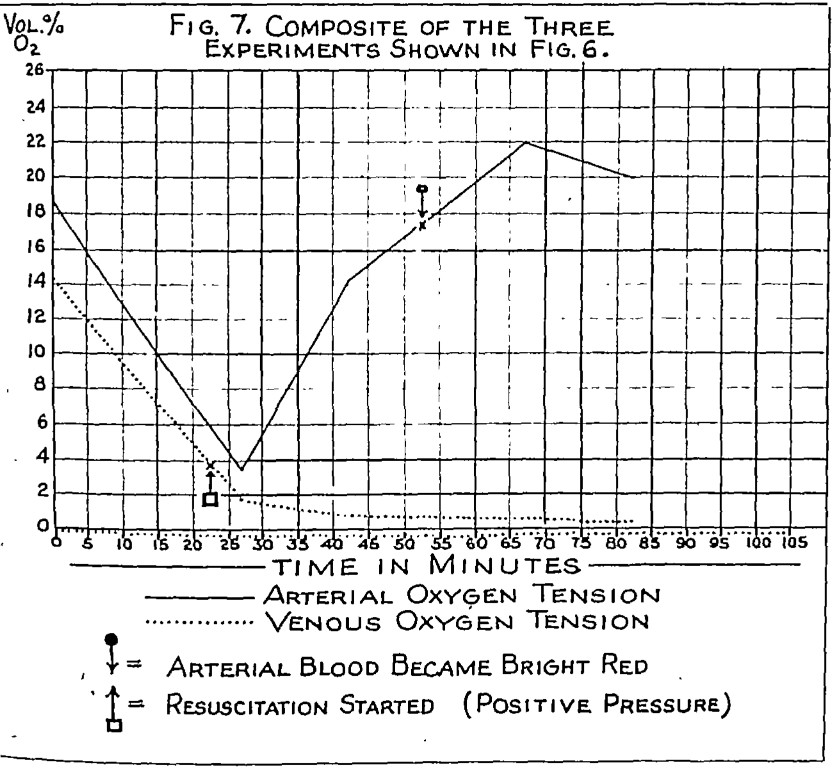

FIG. 7.—This is a composite of the three experiments in Fig. 6. The arterial blood oxygen tension rose rapidly in the first twenty minutes of resuscitation. This curve is inferior to that of Fig. 3, where positive and negative pressures were used. (Courtesy of *Surg., Gynec. & Obst.*)

A further study of the records shows that there is little difference between inflation alone or deflation alone, although a slightly better result is obtained with deflation. Neither of these when used alone can compare in efficiency with the combination of the two.

The controls in which no heparin was used showed the value of this drug in resuscitation. As long as the blood remains in a fluid state it can be circulated over the entire body by the artificial respiration. Once intravascular clotting has occurred there is no longer the possibility of blood circulation and this is the end of all successful resuscitation. Heparin prevents intravascular clotting and keeps the blood in a fluid state and thus prolongs the possible resuscitation time.

In mechanical inflation and deflation of the lungs we have a method of producing pulmonary ventilation as well as circulation of the blood.

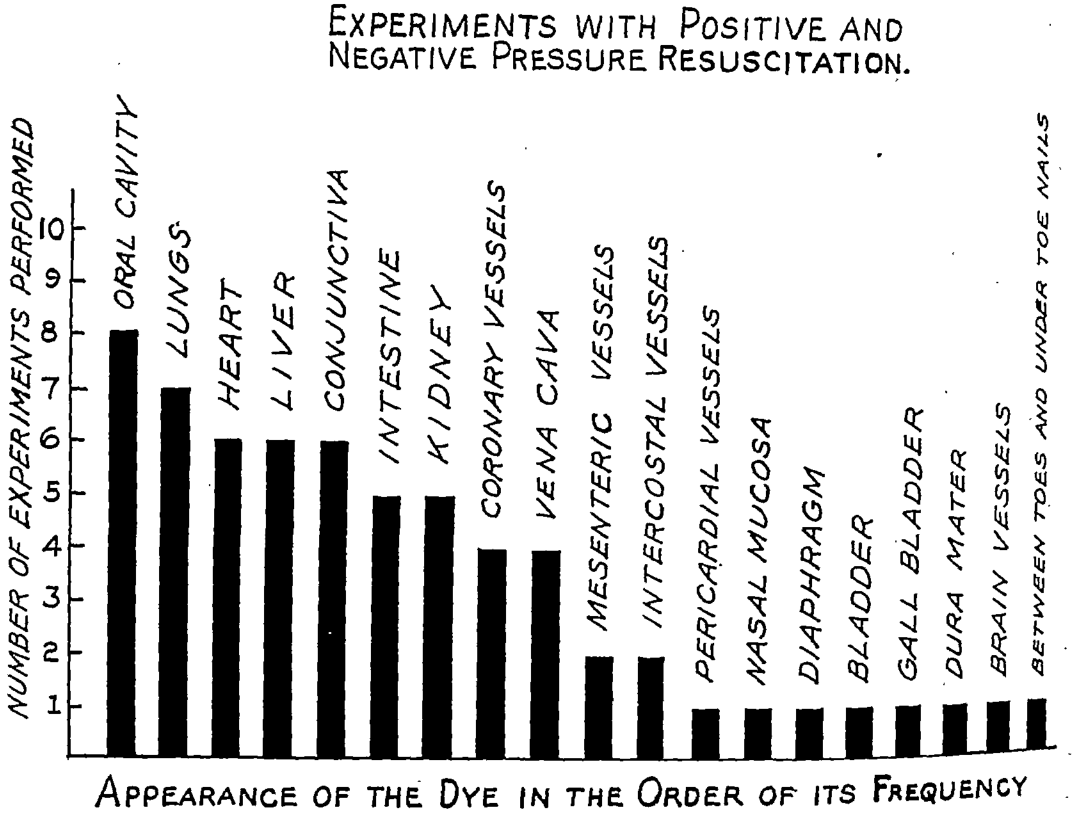

Fig. 8.—Appearance of the dye at various sites when alternating positive and negative pressures are used.

CONCLUSIONS

We have described a method of observing the effect of mechanical artificial respiration upon the circulation when the heart is no longer beating. This is done by the introduction of tracer substances into the vascular system of animals immediately after death and by observing the movement of these tracers while the lungs are inflated and deflated. The tracers used were radioactive sodium, fluorescein, and oxygen.

By this method we have shown that the mechanical inflation and deflation of the lungs produces an actual movement of the blood column and that the blood can be circulated in this way over the entire body without the benefit of any heart action whatever. The clinical application of this knowledge in resuscitation is of twofold importance: (1) the oxygenated blood in the pulmonary capillaries would be transported to the brain and heart; (2) intravascular medications would also be transported to the vital centers of the body.

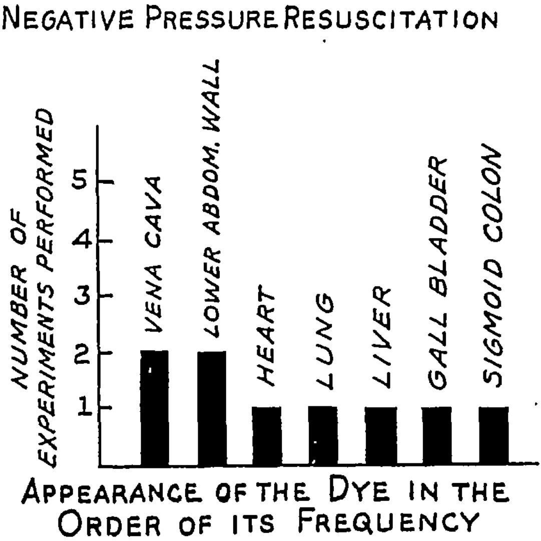

Fig. 9.—Appearance of the dye at various sites when negative pressure only (suction) was used.

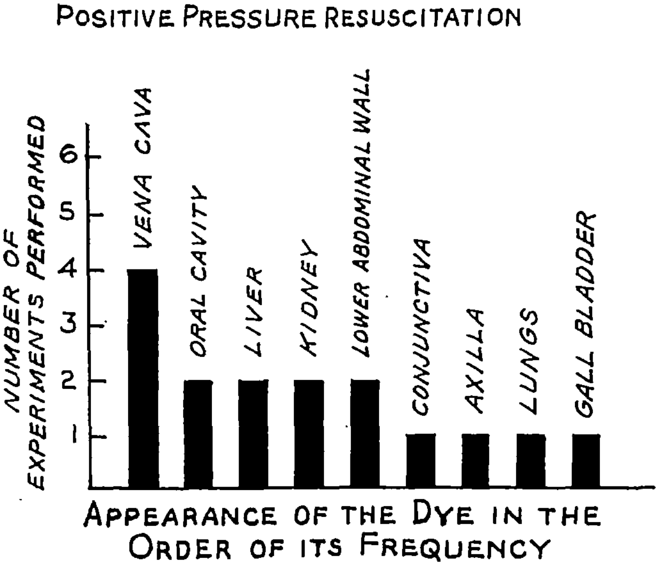

Fig. 10.—Appearance of the dye at various sites when positive pressure only was used.

The value of heparin in resuscitation has been demonstrated.

Those mechanical resuscitators employing alternating positive and negative pressures were by far more efficient in circulating the blood than were those machines employing only positive or negative pressures alone.

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DISCUSSION

DR. JOHN H. GIBBON, JR., Philadelphia, Pa.—I think Dr. Thompson is to be congratulated on his lucid presentation of these accurately controlled experimental observations.

He has conclusively demonstrated, by at least three methods, that a circulation of blood occurs when the lungs are subjected to alternate positive and negative air pressures. This work confirms the remarks which Dr. Beck made in commenting on Dr. Mautz' paper, that a mechanical respiratory apparatus is of considerable value in resuscitating patients.

I should like to ask Dr. Thompson two questions. Is there a slight suction effect through the left side of the heart when samples of arterial blood are removed to determine their oxygen content? I rather imagine that this does not occur, because there was a considerable difference between the effects of positive and negative pressure together, and positive pressure alone, or negative pressure alone.

The second question I would like to ask him is whether he made any observations on pulmonary edema in these lungs. The method of killing the animal by complete obstruction of the trachea, with the marked respiratory efforts which are made, should tend to produce a considerable amount of pulmonary edema.

DR. SAMUEL A. THOMPSON, New York, N. Y.—Thank you very much, Dr. Gibbon.

The movement of blood, or, rather, the movement of any section of the blood column, produces a corresponding movement of the blood above and below that section which is moved, and this same question had occurred to us; namely, that if, by frequent removal of blood samples from the femoral artery, we would not perhaps suck our tracer substance—in this instance, oxygen—down from the lungs toward the femoral artery. We did a control on one animal in which no inflation or deflation was used, and the blood oxygen level stayed the same; there was no change.

As to the presence of pulmonary edema, the pathology of asphyxia is the same as passive congestion. It occurs not only in the lungs, but in all the organs of the body, and we made no particular observation as to the development of pulumonary edema.

THE REGENERATION OF DEFECTS OF THE TRACHEA AND BRONCHI: AN EXPERIMENTAL STUDY

ROLLIN A. DANIEL, JR., M.D.
NASHVILLE, TENN.

IN 1940, Taffel published his findings on the repair of tracheal and bronchial defects in dogs with free grafts of fascia. These defects were created by the excision of full-thickness windows from the cervical trachea. Patches of fascia were securely sutured in place to cover the openings. The open ends of bronchi following lobectomy and pneumonectomy were covered with grafts of fascia in the same manner. He found that the healing process followed the same pattern in all animals. The fascia was replaced by dense, collagenous connective tissue. The bronchial mucosa usually had completely covered the defect in two weeks. The epithelial cells were low cuboidal or flattened at first but later appeared normal. Mucous glands appeared in the submucosa after the third week. New cartilage cells were seen at the cut ends of the tracheal and cartilage rings but this new cartilage appeared to take little part in filling the original defect. The animals were sacrificed at intervals of from one to twelve weeks.

Our interest in this problem was aroused by the observation of a patient, a physician 42 years of age, who died of carcinoma of the trachea two years after the diagnosis was made. He had been treated at intervals with interstitial radiation in the form of radon seeds implanted through the bronchoscope, and with deep roentgen therapy. He came under our care four weeks before he died. The lesion was located about 4 cm. above the carina. His death was due to tracheal obstruction.

The experimental study reported here was undertaken to determine the feasibility of the use of rigid tubes to bridge defects in the trachea and primary bronchi. This study is still in progress.

METHODS

Forty-two mongrel dogs were used in this study. The weight of the animals varied between 8 and 20 kg. Large dogs were used in most of the experiments. The ages of the animals are not known.

All operations were carried out under aseptic conditions, using sodium-pentobarbital anesthesia administered intravenously. Intermittent insufflation of air was delivered through an intratracheal catheter.

Three types of experiments were carried out:

GROUP I.—A part of Taffel's work was repeated. Thirteen dogs were used. The anterior wall of the trachea was exposed through a longitudinal incision in the neck. Windows, about 8 mm. square, were created through the full-thickness of the wall of the trachea.. The methods of closure of these defects are outlined below. The wound of the soft tissues of the neck was closed in layers with fine interrupted silk sutures. Twelve animals survived.

From the Department of Surgery, Vanderbilt University School of Medicine, Nashville.

Read at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

(a) In three dogs the defects were covered with free grafts of fascia, using interrupted fine silk sutures as was described by Taffel. The dogs were sacrificed two, four, and eight weeks postoperatively.

(b) In seven dogs the defects were covered with a layer of "fibrin film" sutured in place with overlying sutures of silk.

There was one death in this group, due to obstruction of the trachea by the film which slipped into the lumen of the trachea on the third postoperative day. The remaining animals were sacrificed at intervals from three days to twelve weeks after operation.

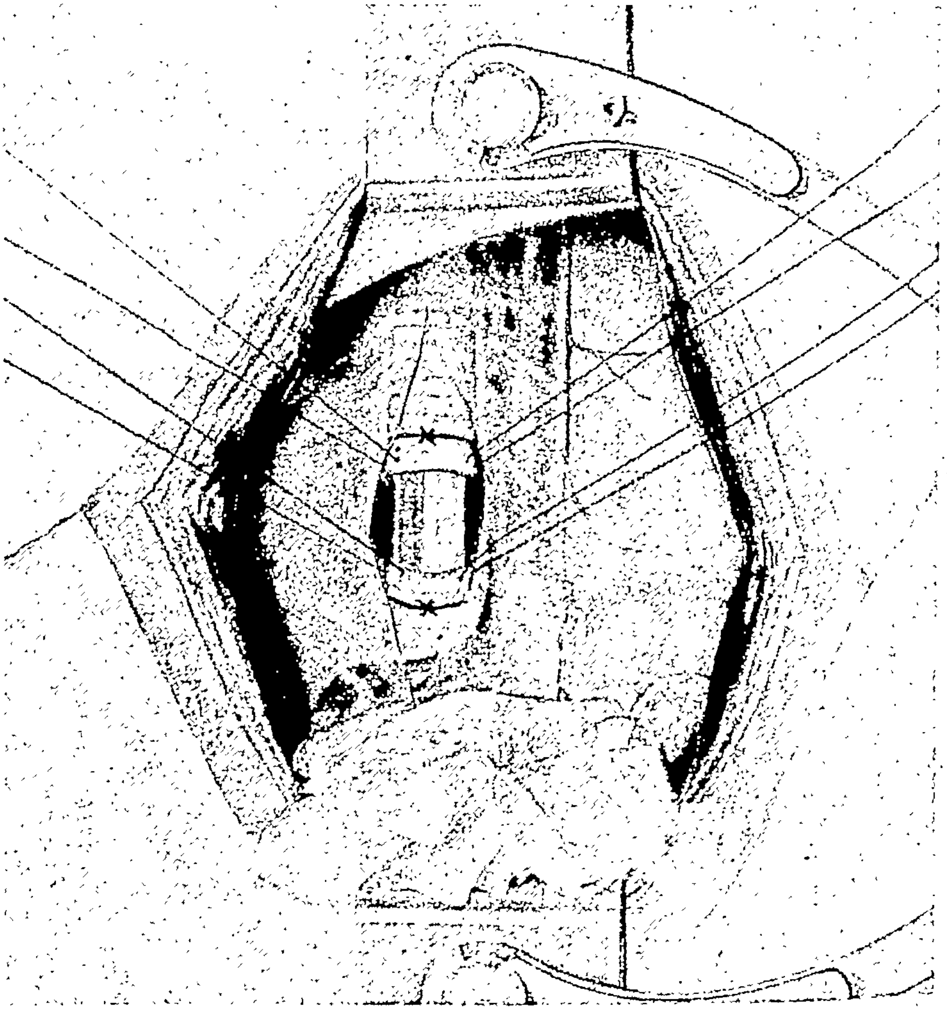

Fig. 1.—Showing method of fixation of tube used to bridge defects in trachea.

(c) In three dogs the tracheal windows were covered by simply suturing the overlying cervical connective tissue tightly over the trachea. These animals all survived, and were sacrificed two, four, and six weeks after operation.

Group II.—Twenty-one animals were operated upon. The right thorax was entered through the right third intercostal space. The mediastinal pleura was incised over the trachea and the trachea was freed from the loose connective tissue which normally surrounds it. Using a sharp scissors or knife, a segment of the trachea was excised. A metal or glass tube was then quickly inserted into the proximal or distal cut end of the trachea and was tied in place with an encircling ligature of heavy braided silk. The remaining cut end of the trachea was drawn over the other end of the tube and was anchored with an encircling ligature. The average time required to accomplish the insertion and fixation of the tube was three minutes and the maximum time was five minutes. Great care was taken to cut across the trachea between the cartilage rings. There was considerable retraction of the cut ends of the trachea and tension on the braided silk ligatures when they were tied around the tube (Fig. 1). When the tube was fixed in place, the mediastinal connective tissue and pleura were brought together with interrupted silk sutures and the wound of the chest wall was closed in layers.

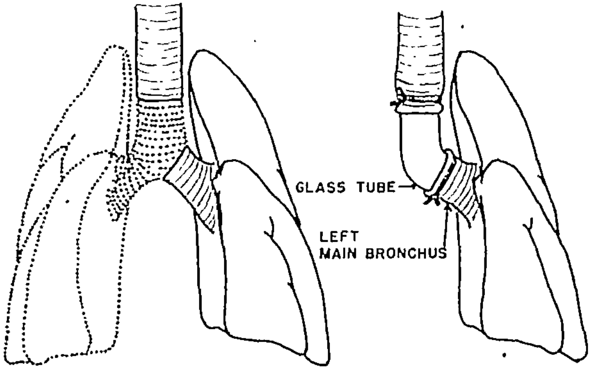

Fig. 2.—Diagram showing structures excised from Dogs 102 and X-14. The method of fixation of the glass tube into the ends of the trachea and left main bronchus are also illustrated.

The tubes were made of glass, stainless steel, or vitallium.* The success or failure of the experiment appeared to have no relation to the kind of material used in the tube. The inside diameter of the tubes varied from 8 to 10 mm and each tube had a flange about 1.5 mm. high near or at each end which prevented the tube from slipping out of the ends of the trachea when the encircling ligatures were tied in place (Fig. 4).

Six animals died within five days after the operation. Two died within six hours and autopsy revealed death to have been caused by the presence of blood in the trachea and bronchi. In three animals death was due to the cutting through of the ligatures and leakage of air from one end of the tube. One of these animals died on the second and two others on the third postoperative days. The sixth dog died five days after operation of massive pleural effusion. The tube was held firmly in place and there was no infection.

The remaining fifteen animals were sacrificed at intervals of from two weeks to six months (Table I). The trachea was removed and microscopic sections were made after fixation of the specimen in a 10 per cent solution of formalin.

GROUP III.—Eight animals were operated upon in this group. The right thorax was opened through the fifth intercostal space. The entire right lung, the lower end of the trachea (four cartilage rings) and the upper end of the left main bronchus (one cartilage ring) were excised "enbloc." A curved tube with flanges at each end was tied into the end of the trachea and the end of the left main bronchus (Fig. 2).

The mediastinal pleura was closed over the tube with interrupted silk sutures and the wound of the chest wall was closed in layers with interrupted sutures of silk.

Only two dogs survived this operation. One of these animals was sacrificed six months after operation and the other fourteen months after operation. In the first six experiments vitallium tubes which were bent to an angle of about 120 degrees were used. The lumen of the tube was smaller at the lower (bronchial) than at the upper (tracheal) end. The flanges were constructed about 3 mm. from the ends of the tubes.

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*The vitallium tubes used in this study were furnished by the Austenal Laboratories, Inc., 224 E. 39th St., New York, N. Y.

The causes of death in these six animals were as follows: Three animals died from leakage of air into the pleural cavity and collapse of the lung. The ligature at the lower end of the tube had cut through the bronchus and the tube and bronchus had come apart. Death occurred two, five, and six days after operation. Two animals died within six hours after completion of the operation and their deaths were caused by impingement of the side of the lower end of the tube upon the upper lobe bronchus, causing occlusion of the lumen of the bronchus. The sixth animal died about six hours after operation from hemorrhage from the cut end of the azygos vein, which had been divided at operation between ligatures to allow adequate exposure of the trachea and the hilum of the right lung.

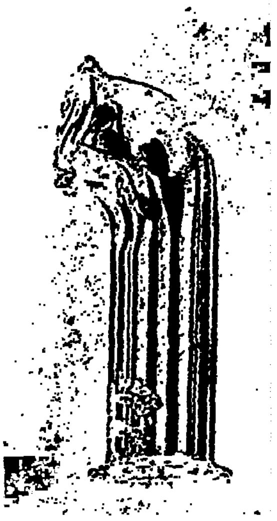

Fig. 3.

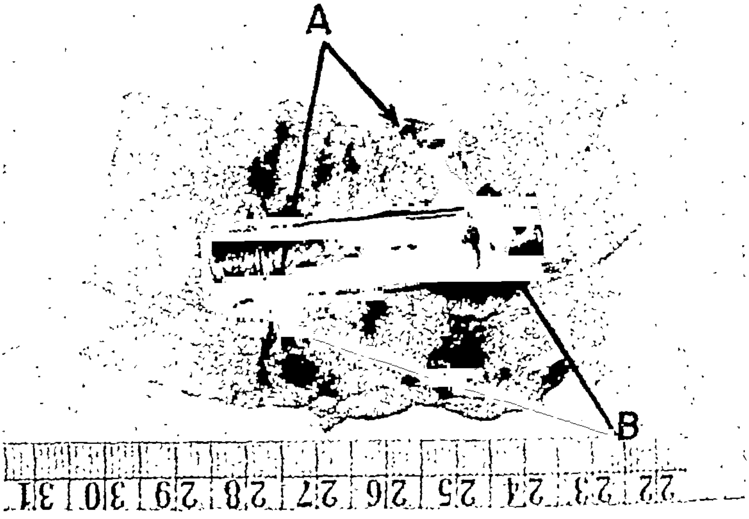

Fig. 4.

Fig. 3.—Photograph of the type of curved tube used in experiments No. 102 and X-14.

Fig. 4.—Dog 2-B sacrificed three weeks after operation. *A*, Silk markers. *B*, Braided silk ligature.

In the last two experiments tubes were used which were made from Pyrex glass test tubes having inside diameters of 9.5 mm. These tubes were curved to an angle of 90 degrees and the flanges were placed at the ends of the tubes (Fig. 3). These animals were sacrificed six months and fourteen months after operation.

DISCUSSION OF FINDINGS

Group I.—(a) The three animals in this group in which fascia grafts were used were sacrificed two, four and eight weeks after operation. There had been no apparent leakage of air from the trachea and no respiratory difficulty was noted. The wounds were all well healed. The trachea appeared to be very slightly narrowed in the animal which lived for eight weeks. The findings were otherwise exactly as have been described by Taffel, both on gross and microscopic examination.

(b) The findings in these experiments were somewhat different. The six animals which survived were sacrificed at three days, one week, three weeks, four weeks, and twelve weeks. At three days the fibrin film was found to be fixed tightly in place. The overlying connective tissues were rather firmly attached to it. Microscopic sections showed invasion and beginning replacement of the film by granulation tissue, growing from the cut edges of the trachea and from the overlying connective tissues of the neck as well. There was beginning regeneration of flattened epithelium at the edges of the tracheal defect. At one week the film was not recognizable grossly or on microscopic section. The entire defect was filled with granulation tissue which was thickly infiltrated with leucocytes. There was some regeneration of epithelium at the edges. At three weeks epithelium had completely covered the inner surface of the trachea. In the center it was composed of a single layer of flat cells. The granulation tissue and fibrous connective tissue underlying the epithelium were still infiltrated with many leucocytes. The trachea was narrowed slightly and

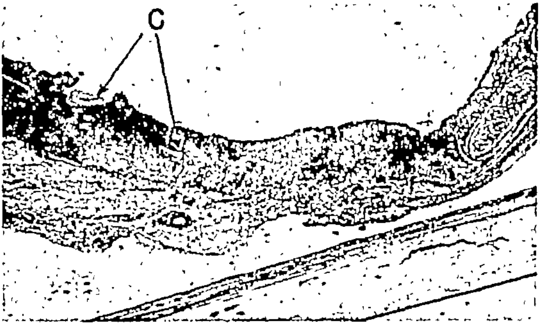

Fig. 5.—Microphotograph of wall of trachea removed from Dog 2-B. C, New cartilage (about ×10).

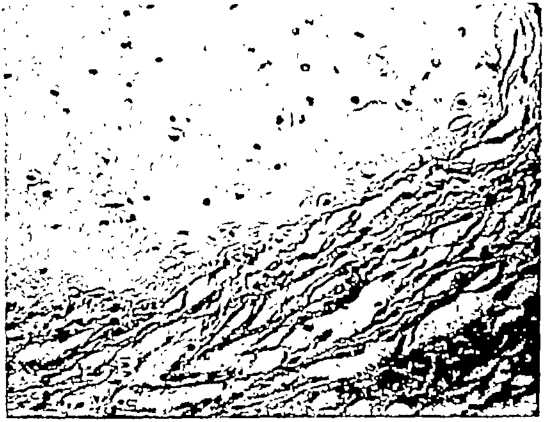

Fig. 6.—High power microphotograph (about ×200) showing the border of smaller cartilage ring shown in Fig. 5.

TABLE I. DEFECTS OF THE TRACHEA

DOG NO.	NO. CARTILAGE RINGS EXCISED. TYPE TUBE USED	TIME AFTER OPERATION ANIMAL SACRIFICED	FINDINGS	
			GROSS	MICROSCOPIC
1. 2-C-1	2 vitallium	2 weeks	Clean granulation tissue covers defect; ligatures have cut through, lie against tube (no silk markers).	Small island new cartilage growing from edge of old cartilage ring; three areas of homogenous, neutrophilic ''matrix'' having small cells scattered through it; beginning growth of epithelium near end of defect.
2. E-12	3 stainless steel	2½ weeks	Clean granulation tissue around tube; ligature lying against tube (no silk markers).	One very small island cartilage near one end of defect; granulation tissue fills defect elsewhere; beginning growth of granulation tissue at ends of defect.
3. 2-B	3 vitallium	3 weeks	Clean granulating surface; silk markers around cartilage rings at each end of defect.	Three small islands of cartilage in thick layer of granulation tissue; epithelium beginning to grow from cut ends over granulating surface.
4. 3-B	3 vitallium	4½ weeks	Clean granulating surface; silk markers in place.	Two islands new cartilage in thick layer of granulation tissue; beginning growth of epithelium from cut ends of defect.
5. 2-C-2	3 vitallium	5 weeks	Tube displaced inferiorly; moderate stricture of trachea; surface clean granulation tissue; silk markers in place.	Two areas new cartilage near one end of defect; two other areas of homogenous ''matrix'' which is acidophilic and one small island cartilage near opposite end of defect; slight growth of epithelium.
6. 9-C	2 vitallium	5 weeks	Clean granulating surface; tube held tightly in place; silk markers in place.	Two small islands of cartilage near one end; thick layer of granulation tissue; early growth of epithelium.
7. 329 E-1	1 vitallium	5½ weeks	Tube held tightly in place by scar tissue covered with clean granulation tissue (no silk markers).	One fairly well-developed cartilage ring in thick layer of granulation tissue in middle of defect; epithelial growth at ends of defect.
8. X-5	4 vitallium	6 weeks	Tube firmly held in place; surface of defect clean, pink, smooth—wall firm; silk markers in place.	Three distinct cartilage rings, irregular in form, lying in thick layer of granulation tissue; epithelial regeneration at ends of defect.
9. X-42	12 glass	6 weeks	Tube held firmly in place; silk ligature lying against glass tube; surface of defect smooth, pink, clean.	Only two cartilage rings—one 1 cm. from lower end of defect—another 1 cm. from upper end of defect; thin layer of granulation tissue; dense collagenous connective tissue underlying granulations; early epithelial regeneration.

TABLE 1—CONT'D

DOG NO.	NO. CARTILAGE RINGS EXCISED. TYPE TUBE USED	TIME AFTER OPERATION ANIMAL SACRIFICED	FINDINGS	
			GROSS	MICROSCOPIC
10. 222	3 vitallium	6½ weeks	Tube firmly in place, held by scar; surface clean granulation tissue; silk markers in place.	Three rings of new cartilage; thick layer granulation tissue and fibrous connective tissue; epithelial growth at ends of defect.
11. 326	3 vitallium	8 weeks	Tube held firmly in place by scar tissue; surface smooth, glistening granulation tissue (no silk markers).	Six rings of new cartilage, small well developed; growth of epithelium at ends of defect.
12. 14	3 stainless steel	8 weeks	Tube held firmly in place by scar tissue; surface smooth, glistening granulation tissue; silk markers in place.	Three islands (rings) of cartilage, not as well developed as in Dog 326; early growth of epithelium at ends.
13. 22	3 stainless steel	10 weeks	Tube firmly in place; smooth glistening granulating surface against tube (no silk markers used).	Three islands (rings) of cartilage; fairly well developed but much smaller than the normal adult tracheal rings; beginning growth of epithelium.
14. 309	13 glass	9 weeks	Tube in place; inner surface glistening; defect about 1 cm. shorter than at completion of operation (length of original defect: 5 cm.); silk markers in place.	Five islands of cartilage, fairly well developed—two near one end of defect, three near the other; 2 cm. area in center contains no cartilage; moderate regeneration of epithelium at each end.
15. 144	4 stainless steel	6 months	Almost complete regeneration of mucous membrane; tube firmly held in place: wall around tube very firm, white (no silk markers used).	Two well-developed rings of cartilage with flattened epithelium bearing no cilia covering these; two other rings, smaller and less well developed in granulation tissue and scar tissue in area not yet covered by epithelium.

there appeared to be a definite diminution in the size of the defect. At four weeks most of the leucocytes had disappeared and the granulation tissue had been converted into dense adult fibrous connective tissue. The diameter of the trachea was markedly narrowed, the ends of the cartilage rings being only 2 mm. apart. At the end of twelve weeks the findings were much the same. Healing was complete and there was moderate stricture due to contracture of scar tissue. The epithelial cells were taller and most of them bore cilia.

(c) The healing of the defects in three animals in which no graft was used, differed slightly from those in which fibrin film was used. These dogs were sacrificed two, four, and six weeks after operation. In all three the soft tissues of the neck had protruded into the lumen of the trachea. Epithelial regeneration was not complete in any of them, although, it was almost complete in the animal which lived for six weeks. There was some tracheal obstruction, due to the protrusion of granulation tissue into the trachea, and, in the animal sacrificed at six weeks, to diminution in the size of the defect.

Group II.—A summary of the data obtained is shown in Table I. The animals which did not survive the operative procedure are not included.

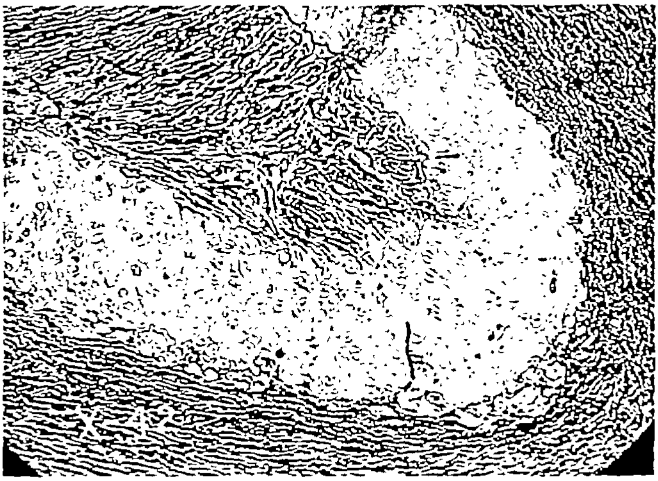

Fig. 7.—Dog X-42, sacrificed six weeks after operation. Microphotograph (about ×60) showing new cartilage cells growing in granulation tissue 1.5 cm. from the upper end of the tracheal defect.

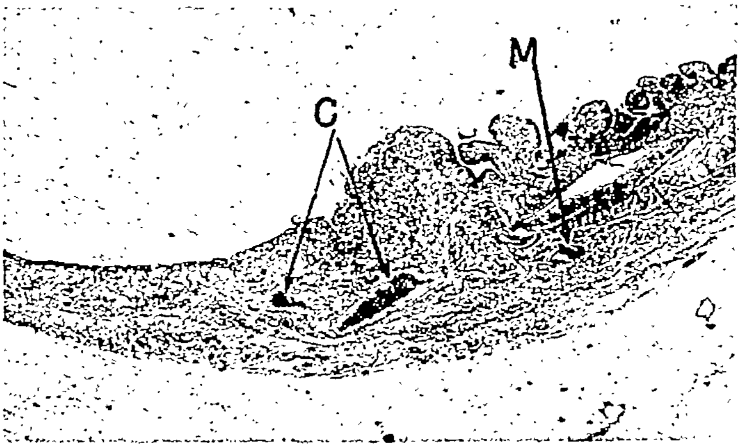

Fig. 8.—Dog 222, sacrificed six and one-half weeks after operation. Low power microphotograph (about ×12) showing old cartilage ring and two islands of new cartilage. *M*, Silk marker adjacent to old cartilage ring. *C*, New cartilage ring.

In all but one dog the tube was held firmly in place by fibrous tissue and granulation tissue which enveloped it. The tube in dog 2-C-2 had slipped downward and its lower end was against the carina. This animal coughed frequently and had wheezing respiration for about a week before he was sacrificed. The remaining animals all tolerated the tubes well. They recovered quickly from operation, breathed comfortably, and, despite the fact that the lumen of the tube was in every case considerably smaller than the trachea, wheezing was noted only occasionally.

In all experiments the braided silk ligatures had completely cut through the trachea and were lying against the tube. Small amounts of thick mucus were often present in the tubes and in the trachea. The silk markers referred to in Table I were sutures of fine silk, placed around the tracheal cartilage ring adjacent to the retracted cut ends and tied loosely. Two ties, one anterior and one posterior, were placed at the proximal end and two at the distal end (Fig. 1). These were used in a number of experiments in order to identify definitely these cartilage rings and to rule out the possibility that the ends of the trachea had been pulled together by the contracture of scar tissue. The markers were identified easily at autopsy in all animals in which they were used (Fig. 4).

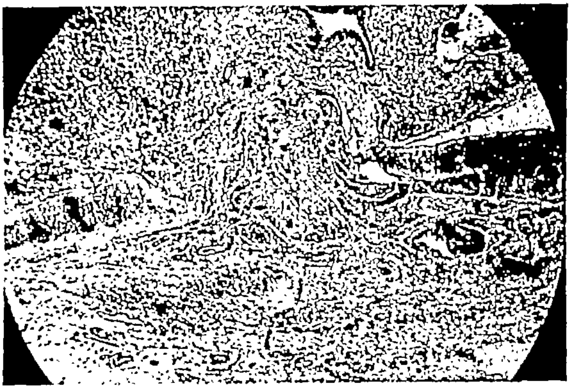

Fig. 9.—Dog 222. Microphotograph (about ×30) showing part of old cartilage ring with silk marker below it and part of new cartilage ring.

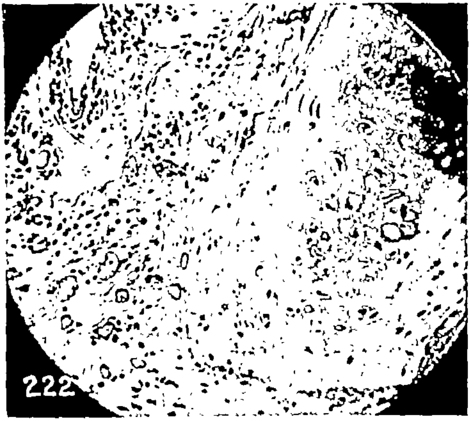

Fig. 10.—Dog 222. Microphotograph (about ×200) showing margin of small cartilage ring in Fig. 8.

Microscopic examination of the specimen removed from dog 2-B, sacrificed three weeks after operation, showed a thick layer of granulation tissue which was densely infiltrated with leucocytes. In the midportion of the defect two small islands of cartilage were present (Figs. 5 and 6). These areas of cartilage were not found in the specimen removed from dog 2-C-1, sacrificed two weeks after operation. In dog E-12, one small nest of new cartilage cells was seen near the end of the defect.

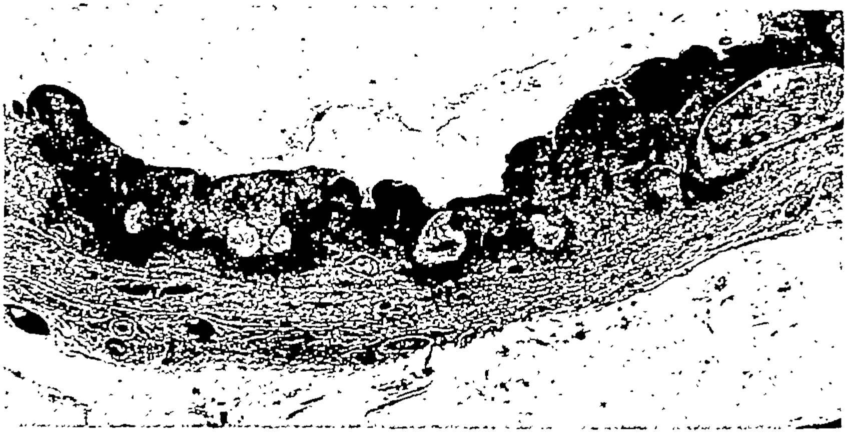

Fig. 11.—Dog 326, sacrificed eight weeks after operation. Microphotograph (about ×12) showing one old cartilage ring and several new poorly developed cartilage rings in the granulation tissue which have been cut at right angles; early regeneration of epithelium can be seen in one end of section.

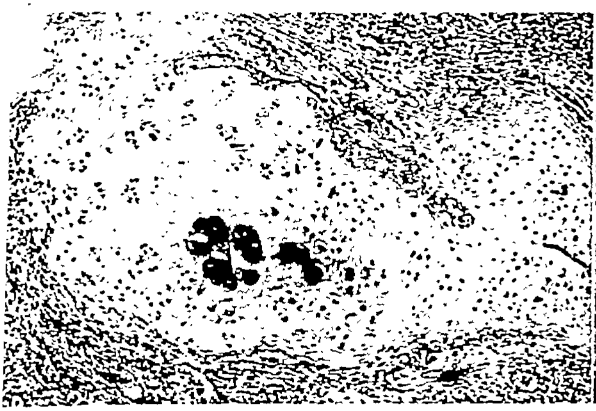

Fig. 12.

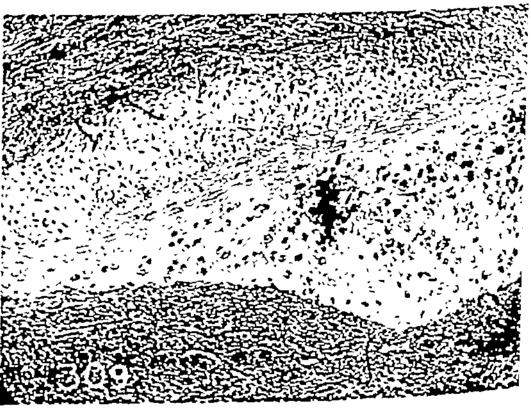

Fig. 13.

Fig. 12.—Dog. 326. Microphotograph (about ×60) showing small island of new cartilage surrounded by granulation tissue in midportion of defect shown in Fig. 11.

Fig. 13.—Dog 309, sacrificed nine weeks after operation. Microphotograph (about ×60) of an island of new cartilage.

In all the remaining animals, sacrificed at intervals of from four and one-half weeks to six months (Table I), these islands of new cartilage were found (Figs. 7 to 15). Sections made longitudinally at various planes around the circumference of the scar showed that many of these islands of cartilage grew in the form of delicate rings, which in some cases extended around through the entire wall of scar tissue which encircled the tube. Although the cartilage first appeared three weeks after operation, its subsequent growth was slow. Dog 144, sacrificed six months after operation, showed two well-developed rings of cartilage (Fig. 14) and two others which were smaller and were composed of nests of cartilage cells which were believed to be less mature. These cartilage rings began their growth in many instances well out in the granulation tissue, away from the preformed adult cartilage rings of the trachea and near the surface of the tissue opposed to the tube (Fig. 5). The fibroblasts in the granulation tissue appear to have been the anlage of the cartilage cells. Examination of the borders of the cartilage islands revealed a gradual change from the fibroblasts in the granulation tissue to a cell which was surrounded by a capsule, was larger, vacuolated, and contained a large eccentrically placed nucleus (Figs. 12 and 15).

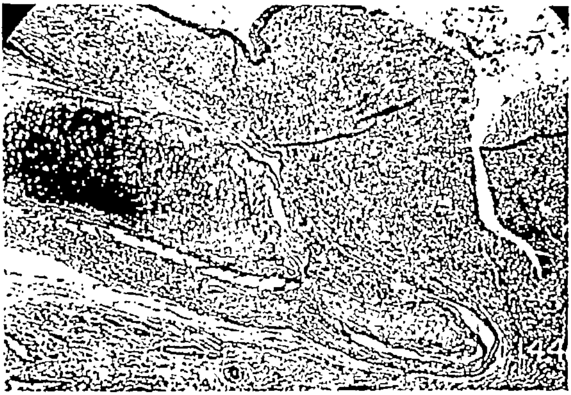

Fig. 14.—Dog 144, sacrificed six months after operation. Microphotograph (about ×30) showing a large, well-developed island of cartilage. Regenerated epithelium can be seen covering a part of the defect.

Occasionally two nuclei were seen in one cell. A homogenous neutrophilic matrix was laid down around these cells and this matrix became basophilic after a few weeks' time had elapsed. The stroma of granulation tissue was then gradually converted into adult fibrous connective tissue.

The growth of epithelium from the cut ends of the trachea began early but had not completely covered the granulating surface in any of the animals in this group. In dog 144, sacrificed six months after operation, epithelial regeneration was almost complete, however. The cells were flat and extended outward toward the middle of the defect in a single layer. The epithelium then became thicker, composed of more than one layer of cells which had a stratified appearance as growth toward the midportion of the defect progressed more slowly (Fig. 14).

Group III.—The two animals in this group which survived were sacrificed six months (No. 102) and fourteen months (No. X-14) after operation. No. 102 began to have violent paroxysms of coughing about two weeks before death.

There was also rather marked wheezing with respiration which gradually became worse. He became malnourished and was sacrificed because of his increasing discomfort. Autopsy revealed the tube to be firmly held in place by scar tissue which encircled it. There was mucopurulent exudate present in the trachea, the tube, and the bronchi of the left lung. There was patchy consolidation throughout the remaining lung and death was thought to be due to pneumonia. Unfortunately, this specimen was lost after its removal and before photographs

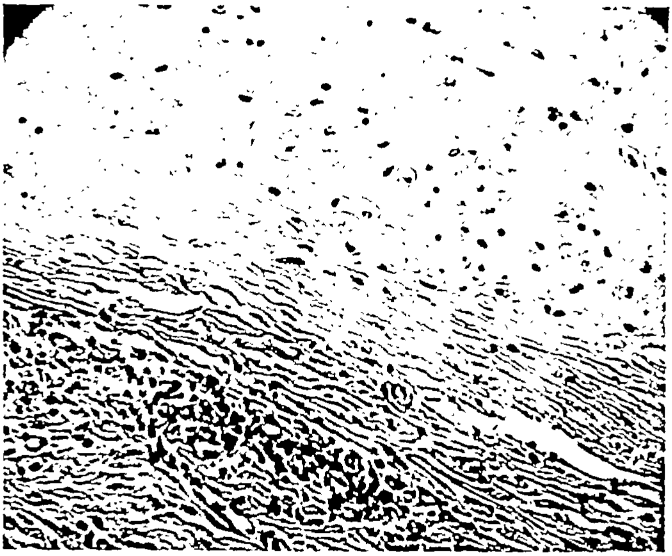

Fig. 15.—Dog 144, sacrificed at six months after operation. Microphotograph (about ×150) showing border of small nest of cartilage cells. Gradual differentiation of fibroblasts (seen in lower portion of picture) into cartilage cells, is clearly shown.

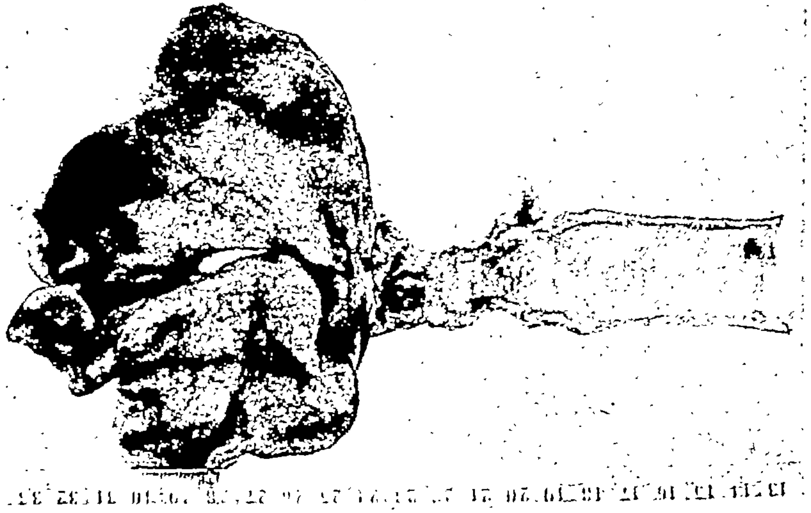

Fig. 16.—Dog X-14. Specimen removed at autopsy. A segment of the lower trachea is shown and the markedly narrowed trachea and bronchus can be seen extending between the hilum of the lung and the lower trachea. The regrown rings of cartilage are also pictured.

or microscopic sections were obtained. Grossly there was almost complete regeneration of the epithelium. The surface of an area which varied from 0.5 to 1.0 cm. in width, in the central part of the defect, appeared to be composed of pink, smooth, firm granulation tissue. The scar tissue underlying the mucous membrane and granulation tissue was very firm and white. There were definite rings of hard rubbery white material, spaced along the course of the entire wall of the regrown trachea, which had the gross appearance of rings of cartilage. These rings were not as uniform in size or configuration as were those of the normal trachea above the site of excision and their thickness, width, and resistance to pressure varied considerably at different points.

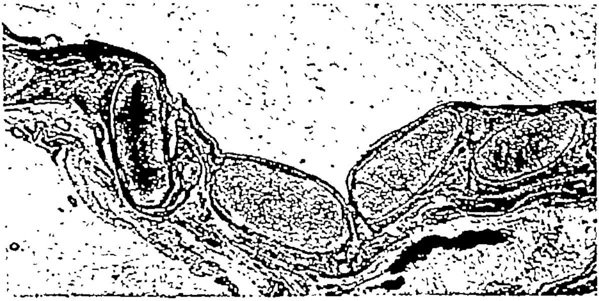

Fig. 17.—Dog X-14, sacrificed at fourteen months after right pneumonectomy. Microphotograph (about ×12) showing part of the regrown lower segment of trachea.

Dog X-14 also began to lose weight and to have paroxysms of violent coughing about seven months after operation. Eight months after operation the animal was subjected to bronchoscopic examination. The glass tube was easily visualized, lying in the lower end of the trachea. It appeared to lie loosely in the trachea and a large amount of mucus was aspirated from the trachea proximal to it. The end of the tube was grasped with a biopsy forcep and it was easily withdrawn from the trachea as the bronchoscope was removed. Examination of the lower trachea then revealed it to be moderately narrowed. The mucous membrane was intact as far down as could be seen, no ulceration being noted.

Following this procedure the animal gained weight and the cough disappeared. When the dog was forced to run he coughed and when respiration became labored he wheezed. No wheezing or cough was noted when he walked or lay in the cage.

The animal was sacrificed at the end of fourteen months at which time he was in good health. The specimen removed at autopsy is shown in Fig. 16. There were well-developed, evenly spaced cartilage rings present, from the normal trachea to the division of the left main bronchus. The mucous membrane was intact everywhere. The diameter of the regenerated segment of the trachea was a little more than half that of the normal trachea above.

The rings of cartilage extended completely around the tube instead of around only a part of the circumference as do the normal tracheal rings.

Microscopic sections of the regenerated segment of trachea showed the cartilage rings to be well developed and mature in appearance (Fig. 17). The cartilage resembled that seen in the rings of the normal trachea above. The arrangement of these rings was not as regular as in the normal trachea, however, and the space between them was more variable. The mucous membrane was composed of a layer of flat epithelial cells which were only one or two layers thick and which bore no cilia. No goblet cells could be seen. A few scattered groups of mucous glands were found lying outside and between the cartilage rings.

COMMENT

The differentiation of fibroblasts into cartilage cells has been noted previously. Maximow and Bloom,[2] LeGros Clark,[3] E. R. Stump,[4] and E. L. Clark[5] and others have maintained that this does occur. It should be emphasized that in the experiments reported here the segments of trachea which were excised included the entire tracheal wall. Care was taken to incise the wall with a sharp knife between the cartilage rings, in such a way that no bits of cartilage or perichondrium would be left in the wound. The fact that cartilage grew in the granulation tissue at varying distances from the remaining catrilage rings at the ends of the defects, and that it tended to grow in the form of encircling rings which were separate from each other, suggests a differentiation of young connective tissue cells into cartilage cells. This is borne out by the microscopic study of the new cartilage and the adjacent stroma.

SUMMARY

Three types of operative procedures have been carried out upon forty-two dogs.

1. In thirteen experiments full-thickness windows have been removed from the cervical trachea. The method of healing of these defects has been observed following closure of the wounds with free grafts of fascia (studied previously by Taffel), with fibrin film and with the connective tissues of the wound of the neck.

2. Full-thickness segments of trachea were excised in twenty-one dogs and rigid tubes were placed across the defects which resulted from excision of the trachea. Fifteen animals survived this procedure. These animals tolerated the tubes well and were sacrificed at intervals ranging from two weeks to six months. It was found that new cartilage could be seen growing in the granulation tissue which surrounds these tubes. Evidence is presented that this cartilage develops as a result of the differentiation of fibroblasts into cartilage cells.

Studies on two other animals, in which the right lung, the lower end of the trachea, and the upper end of the main bronchus were excised "en bloc" are also presented. One of these animals was sacrificed fourteen months after this operation was performed. It was found at autopsy that restoration of the trachea was complete to the extent that there was regeneration of flattened epithelium over the entire wall and the growth of distinct and separate rings of cartilage which completely encircled the tracheal wall and which were fairly uniform in size and arrangement.

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DISCUSSION

DR. JOHN H. GIBBON, JR., Philadelphia, Pa.—This is a very interesting and beautiful presentation. I hope Dr. Harrington and Dr. Gray will say something about the work that is being carried out at the Mayo Clinic along these lines. While carcinomas of the trachea are not very frequent, when encountered they present a difficult surgical problem. If this work can be elaborated and confirmed, we should soon be able to use something of this sort in the human patient, and perform a radical excision of the trachea itself. The use of fascia, or other nonrigid material, does not permit the resection of an entire segment of the trachea.

I had one experience in which I excised a portion of the trachea and the left main bronchus in a patient with a bronchial adenoma. In this patient approximately one-half of the cartilaginous wall had to be excised in order to remove the growth. We were very puzzled as to how to fill the defect. We finally employed a large, pedicled flap of parietal pleura. A portion of one costal cartilage was removed and this piece of cartilage was wrapped up in the pleural flap. The pleural flap containing the cartilage was then sutured over the defect in the tracheal wall. The patient required bronchoscopic dilatation postoperatively, but is now alive with an adequate airway eight months after operation.

I mention this case because, while it cannot be employed where an entire segment of the trachea is removed, it may be a useful method of handling those cases in which partial excision of the trachea and bronchus is sufficient to remove the growth. Incidentally, the patient did very well postoperatively, and went home several months ago.

DR. ROLLIN A. DANIEL, JR., Nashville, Tenn.—First I want to thank Dr. Gibbon and Dr. Harrington for their discussions.

The number of animals which we have used was very small, as you have seen, and the methods which we employed were crude. We do intend to carry out more experiments of this type, and we hope that others will do the same.

EOSINOPHILIC GRANULOMA OF RIB

Elmer Maurer, M.D., and George A. DeStefano, M.D.
Cincinnati, Ohio

DURING the past seven years eosinophilic granuloma of bone has rapidly assumed increasing importance as a specific clinical entity. This particular destructive lesion mimics a variety of neoplastic processes as well as inflammatory conditions, and should be considered in any differential diagnosis in which single or multiple lesions of bone are encountered. Solitary eosinophilic granulomata may simulate bone cyst, giant cell tumor, Ewing's tumor, solitary myeloma, osteogenic sarcoma, and osteomyelitis. Multiple lesions may present the same clinical signs and roentgenographic findings as multiple myeloma, metastatic tumor, osteitis fibrosa cystica, Letterer-Siwe disease, and Hand-Schüller-Christian disease.

In 1929 Finzi[1] described what might be considered the first case of eosinophilic granuloma of bone reported in the literature. The lesion involved the frontal bone of a 15-year-old boy and was thought to be a "myeloma with prevalence of eosinophilic cells." Mignon,[2] in 1930, reported a "granulation tumor of the frontal bone" in a boy 12 years of age. Eight years later Schairer[3] described two cases of osteomyelitis with eosinophilic reaction which occurred in the parietal bones of children 9 and 10 years of age. General recognition was not attracted to this peculiar lesion, however, until 1940, when Lichtenstein and Jaffe[4] first clearly defined the condition as a clinical entity and suggested the term "eosinophilic granuloma of bone." They reported in detail the case of a 4-year-old child in whom a solitary lesion involved the left femur. A definite preoperative diagnosis was not made but osteomyelitis, tuberculous osteitis, and Ewing's tumor were considered as possibilities. The patient made an uneventful recovery following open curettement of the bone cavity and postoperative deep roentgen therapy. In a subsequent communication in 1944 these same investigators,[5] after careful re-evaluation of the microscopic pathological features of this disease, concluded that eosinophilic granuloma of bone, Letterer-Siwe disease and Hand-Schüller-Christian disease may be considered as different clinicoanatomic expressions of the same basic disorder.

Approximately thirty-nine cases of eosinophilic granuloma have been reported to date. Only six of these lesions have been solitary in the rib. Because of the infrequent occurrence of this lesion and its close resemblance clinically and roentgenographically to neoplasms of the chest wall for which surgery is usually recommended, the following report is being made.

CASE REPORT

J. B., a 16-year-old white boy, was admitted to Christ Hospital Aug. 24, 1946, complaining of left anterior chest pain of one month's duration. There was no history of

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From the Departments of Thoracic Surgery and Pathology, Christ Hospital, Cincinnati.

The authors are indebted to Dr. Irving H. Schroth for permission to publish the record of this case.

trauma, weight loss, fever, or cough. The pain was continuous, not exaggerated by deep breathing or coughing, and was increasing in severity.

Physical examination revealed no palpable tumor masses over the left chest. The percussion and auscultatory findings over both lungs were normal.

Laboratory studies were as follows: Blood hemoglobin 86 per cent or 13.5 gm.; R.B.C. 4,320,000; W.B.C. 8,700; differential, normal with one per cent eosinophiles. Sedimentation rate was 13 mm. per hour; serum phosphorus, 4.5 mg. per cent; serum calcium, 10.7 mg. per cent; urinalysis negative.

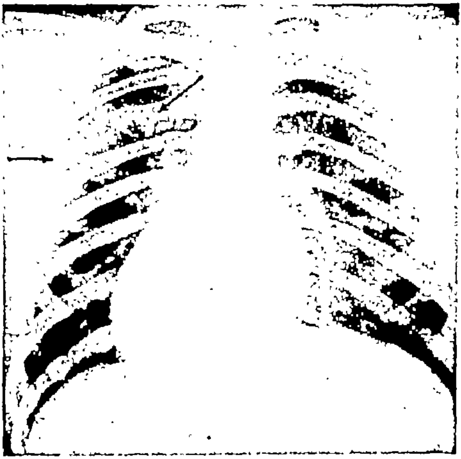

Fig. 1.—Preoperative roentgenogram of the chest showing the destructive lesion in the left fifth rib.

Roentgenogram of the chest, posteroanterior projection, was reported as showing a destructive, expansile process involving the posterior 9 cm. of the fifth rib on the left (Fig. 1). Tangential views of the involved rib revealed some pleural thickening about the lesion. The bone destruction and expanding character of the tumor suggested a primary rib sarcoma. The pleural thickening seemed to be in favor of an infectious process such as osteomyelitis. The roentgenologist concluded that the bone destruction was not characteristic of any particular type of lesion and could be either infectious or neoplastic in origin. Combined fluoroscopic and radiographic examination of the remainder of the skeletal system revealed no other evidence of tumor or bone infection.

Because of the young age of the patient, the posterior location of the rib tumor, and the paucity of complaints except for chest pain, osteogenic sarcoma was thought to be the most probable diagnosis. Focal osteomyelitis and giant cell tumor were also considered in the differential diagnosis.

Operative Procedure.—On Aug. 29, 1946, bloc excision of the fifth rib, transverse process, intercostal muscle, and pleura was performed. At the time of operation a soft, yellowish-red tumor mass was encountered completely replacing the normal structure in the vicinity of the angle of the fifth rib. A small nodule was apparent on the pleural surface of the rib but had not eroded through the parietal covering into the free pleural cavity. The lung was not adherent to the chest wall and showed no evidence of tumor involvement. Closure of the defect after excision of the fifth rib and surrounding chest wall structures was accomplished by suturing together periosteal flaps which were developed from the fourth rib above and the sixth rib below. (Figs. 2 and 3). This resulted in a satisfactory air-tight closure of the chest wall following the instillation of 50,000 units of penicillin.

Pathologic Findings.—The gross specimen consisted of a section of rib 18 cm. in length, with attached transverse process, intercostal muscles, and parietal pleura. Three centimeters from the transverse process the rib presented a fusiform enlargement 7 cm. in length by 2.2 cm. in diameter, tapering at both ends into normal appearing rib. There was a pathologic fracture through the midportion of the lesion. On sectioning, no normal bone marrow could be identified.

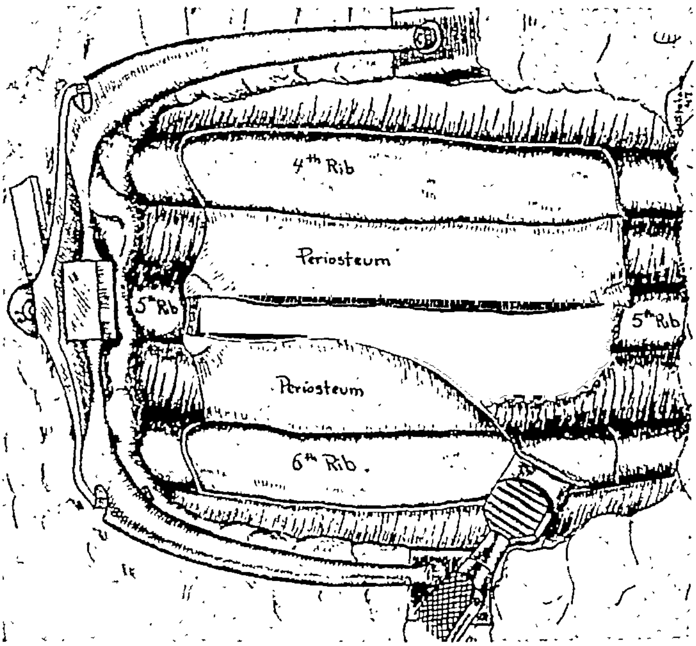

Fig. 2.—Periosteal flaps developed from the fourth rib above and the sixth rib below the defect.

On microscopic examination (Figs. 4 and 5), the tissue had a typical granulomatous appearance. No tubercle formation was evident. The most conspicuous cells were large phagocytic histiocytes which contained large oval nuclei and numerous nucleoli. Interspersed among these histiocytes were sheets of eosinophiles with occasional multinucleated giant cells. The giant cells were actively phagocytic and contained the same reddish brown intracellular bodies which were seen in some of the histiocytes. Plasma cells, lymphocytes, and polymorphonuclear leucocytes were scattered in the section. The supporting stroma was scanty and contained areas of hemorrhage and fibrosis.

Cultures for bacteria were sterile.

Diagnosis: Eosinophilic granuloma of rib.

Postoperative Course.—Convalescence was uneventful. A pleural effusion of approximately 400 c.c. was removed by thoracentesis on the fourth postoperative day. The wound healed per primam and the patient left the hospital twelve days following the operation. Follow-up roentgenogram of the chest, at the time of discharge, showed the left lung to be completely expanded with no evidence of reaccumulation of fluid (Fig. 6). Ten months following operation the patient was well and without evidence of distant or local recurrence of the disease.

DIAGNOSIS

Although originally described as a disease of the very young, eosinophilic granuloma has been found to exist also in the adult. Lesions may be solitary or multiple and may involve all bones of the skeleton except those of the hands and feet. The lesions most commonly occur in the cranial vault, ribs, vertebrae, and the long bones, especially the humerus and femur. Although numerous bones may be simultaneously involved, only one lesion may produce symptoms and attract the attention of the examiner. For this reason, all patients who present themselves with findings suggesting the presence of an eosinophilic granuloma of one bone should be studied radiographically for other bone involvement.

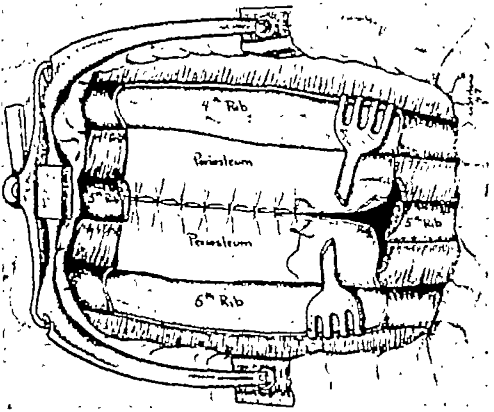

Fig. 3.—Periosteal flaps approximated with interrupted silk sutures.

Eosinophilic granuloma appears to be clinically, histologically, and pathologically a benign lesion of bone which most commonly effects children, adolescents, and young adults, especially males.

The exact etiology of the disease remains unsettled. It has been suggested by Otani and Ehrlich[6] that trauma is a probable cause. Lichtenstein and Jaffe[4] believe the disease may be due to a virus infection with the portal of entry in the gastroenteric tract. Repeated tissue cultures by these investigators, however, have been negative.

The clinical picture is characterized by complaints of short duration, usually a few weeks or months. Local tenderness and pain with or without swelling are common symptoms. There may be systemic manifestations including pyrexia, general malaise, loss of weight, and leucocytosis with eosinophilia ranging from normal to 11 per cent. When these findings are present the correct diagnosis is more easily made. It is more common, however, for the lesion to be completely silent until discovered on the roentgenogram as a destructive process with or without a pathologic fracture in the involved bone. This finding is usually made only after the patient has complained of an obscure pain and weight loss. Such an onset might suggest a rapidly progressing neoplastic process. This was the situation in the case reported.

The roentgenographic appearance of the inidividual lesion of bone is that of a small or large irregularly destructive radiolucent zone with or without signs of periosteal reaction, bone condensation, or pathologic fracture. In the calvarium, scapula, and innominate bones, the lesion may be circular, sharply delimited, or punched out, suggesting a solitary myeloma. In ribs, the affected area in addition to rib destruction, may show expansion of the cortex, and if perforation or fracture has occurred, there will be deposition of periosteal new bone and thickening of the overlying soft tissue. Such roentgenographic findings could also be found in early osteogenic sarcoma of the rib. Because of this lack of distinctive roentgenographic characteristics coupled with the usual history of rapid onset, meager complaints, and clinical findings, it is easy to understand why this lesion is easily confused with neoplasm and osteomyelitis. Also, in cases in which several bones are involved, the roentgenographic findings may suggest multiple myeloma, Ewing's tumor, or metastatic skeletal carcinoma.

PATHOLOGY

The gross appearance of an affected region of bone is usually that of soft, hemorrhagic cystic granulation tissue which may vary from brown to yellow in color and contains numerous areas of necrosis. The lesion is usually well localized in the medullary cavity and tends to erode, expand, and perforate the cortex. At the time of operation the process may already have perforated the cortex and extended into the surrounding soft tissues in a manner that is usual for a malignant bone tumor.

The histologic picture presents a destructive granulomatous lesion characterized by large sheets of phagocytic histiocytes, interspersed among which are numerous eosinophilic cells and multinuclear giant cells. The eosinophiles, although not the basic constituent of the lesion, nevertheless, are responsible for the unusually striking microscopic picture of the disease, and when present in large sheets may produce a red appearance in the cut stained sections. In the late stages of the disease eosinophiles tend to disappear and there is a predominance of large mononuclear cells and fibrosis. Several eosinophilic granulomatous lesions have been observed to heal by resolution.

TREATMENT

Since the final diagnosis is not usually made until histologic examination of the tissue has been completed, one cannot know what would be the course of a solitary lesion which closely resembles neoplasm if it were left undisturbed. For this reason wide surgical excision is suggested as the treatment of choice. Lesions involving the ribs are particularly amenable to this method of treatment. When the lesion occurs in a long bone or the calvarium, healing usually follows thorough curettage. It is now known that complete, spontaneous healing by resolution does occur in some cases within six to seven months. Also, in cases of multiple bone involvement, healing has occurred following roentgen therapy. Since surgical exploration and pathologic examinations are essential, however, in establishing the correct diagnosis, and since most lesions require several months to a year to heal under roentgen therapy, a program of procras-

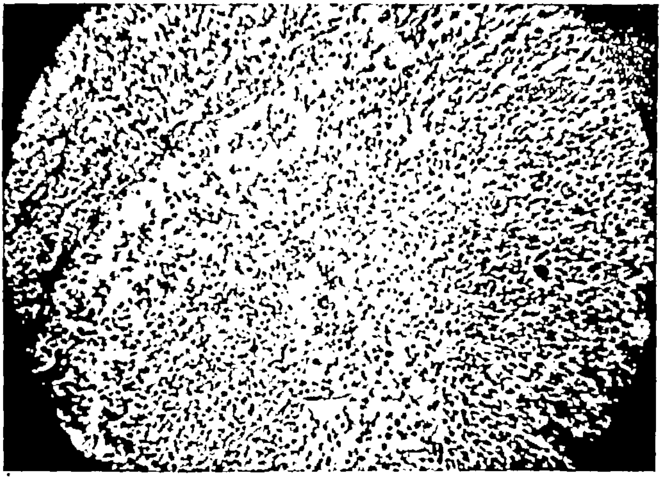

Fig. 4.—Microphotograph low power showing dense sheets of eosinophils.

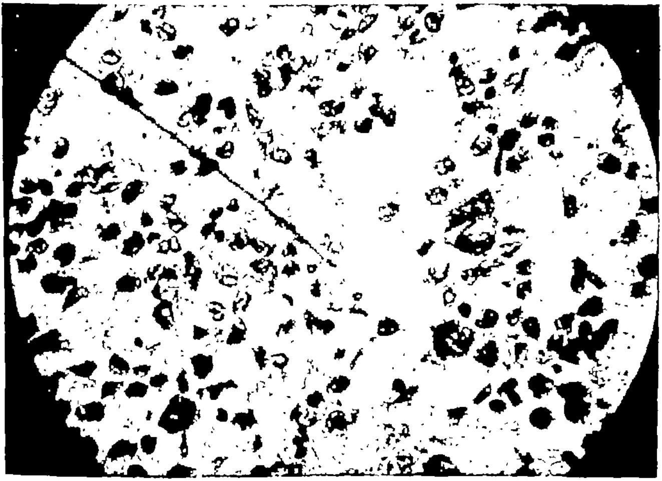

Fig. 5.—Microphotograph high power showing typical multinucleated giant cells with interspersed phagocytic histiocytes.

tination and test radiation therapy is ill advised. It would seem more desirable to treat all lesions of ribs by wide surgical excision. Postoperative roentgen therapy is not suggested.

PROGNOSIS

Eosinophilic granuloma of bone appears to offer an excellent prognosis despite its rapid development, seemingly progressive nature, and ominous roentgenographic appearance. The postoperative reports and observations ranging from seven months to six years made by Jaffe and Lichtenstein[4] on cases treated by excision, curettage, and radiation therapy have all been encouraging regardless of the method of treatment chosen. The prognosis should, however, be guarded in those cases in which multiple lesions are encountered. In such situations, visceral lesions should be sought for and careful consideration given to the possibility of Letterer-Siwe disease, which is usually seen in younger children and manifested by a rapid febrile course with generalized lymphadenopathy, hepatomegaly, splenomegaly, purpura, and anemia.

CONCLUSIONS

1. Eosinophilic granuloma of bone is rapidly becoming more important as a specific clinical entity which must be considered in any differential diagnosis in which single or multiple lesions of bone are encountered.

2. This lesion, when in the rib, should be of particular interest to the thoracic surgeon because of its close resemblance clinically and roentgenographically to neoplasm of the chest wall for which surgery is usually recommended.

3. A case of solitary eosinophilic granuloma of rib with a clinical history and roentgenographic findings consistent with osteogenic sarcoma, is reported.

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BRONCHOSPIROGRAPHY: APPARATUS AND TECHNIQUE

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THE value of determinations of the functional capacity of the two lungs separately has been conclusively demonstrated by the work of a number of authors, notably Jacobaeus,[1] Cournand and associates,[2] Pinner, Leiner, and Zavod,[3] and Adams.[4] Certain technical difficulties encountered by the early workers in this field (Jacobaeus,[1] Frenckner and Bjorkman,[5] Bezancon[6] and others), whose determinations were made with double- or single-lumen rigid bronchoscopes, were largely eliminated by the introduction of the specially constructed flexible catheters of Gebauer[7] and Zavod.[8] These catheters, particularly when used in conjunction with the "twin spirometer" developed by Gebauer,[9] have provided a practical and safe method of estimating the relative function of the separate lungs.

While the chief and most important application of this work has been in the selection of cases for various types of irreversible collapse therapy where clinical and roentgen examinations often fail to allow accurate estimation of the functional capacity of the two lungs, bronchospirometric data have likewise been helpful in the preoperative evaluation of patients in whom resection is contemplated.

Our experience with the double-lumen catheters has, on the whole, been satisfactory, but there have been many instances in which technical difficulties inherent in the apparatus have prevented the recording of satisfactory data. These difficulties were encountered chiefly in patients with poor function, because of the increased respiratory effort required in "stenosis breathing" through the narrow channels of the double-lumen catheter, which seemed inadequate despite the fact that the breathing mixture was rich in oxygen. A number of the patients have seemed actually dyspneic during the test. In some cases, free exchange seemed to be impaired by secretions of large amount or viscid character.

It occurred to one of us (C. M. N.) that a method using a single-lumen endobronchial catheter might be feasible for simultaneous measurement of separate lung function. The apparatus which we have now adopted appears to offer advantages of simplicity in use, comfort for the patient, and added accuracy. The narrow breathing channels of the double-lumen catheter, which make use of only a small percentage of the cross-section area of the adult subglottic airway, have been eliminated. The single-lumen catheter, 22 F. to 26 F., with a distal inflatable cuff, provides the airway to the left lung. After insertion and positioning under fluoroscopic guidance, its outer end is brought through one arm of a Heidebrink Y-connector on a Connell mask of appropriate size. Uninterrupted air exchange to the right lung is thus maintained

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around the catheter to the left lung via the other arm of the Y-connector. There appears to be no tendency for interference with air exchange at the glottic level, provided the larynx has been well anesthetized. Despite the obvious increase in "dead space" for the right lung, there is no indication that this affects the accuracy of the results.

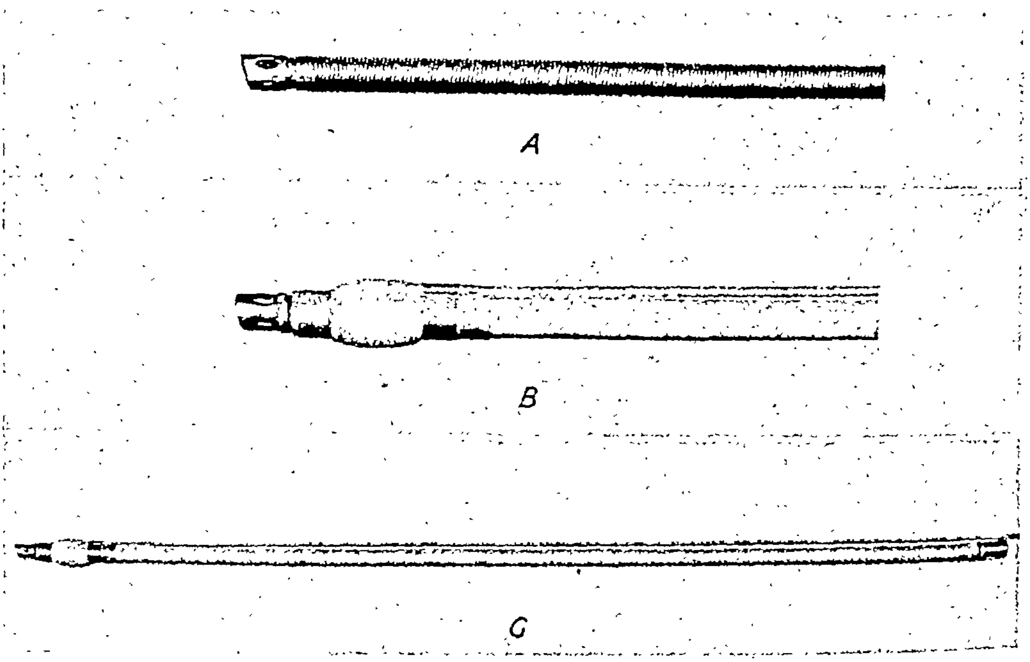

Fig. 1.—Flexible single-lumen catheter for bronchospirography. *A*, Distal end, showing metal spiral construction and beveled tip with lateral breathing holes. *B*, Same, after application of latex rubber sheath and inflatable cuff. *C*, Entire catheter (22-26 F., 55 cm. long).

The catheter* (Fig. 1), 55 cm. in length, is of the flexible metal spiral type, with a short beveled tip providing additional lateral breathing holes. The external diameter of the catheter used for the average adult is 8.7 mm. (26 F.); the internal diameter is slightly less than 7 mm. Air leakage is prevented by sheathing the catheter in latex Penrose tubing, secured by silk ties at the upper and lower ends. The inflatable portion of the cuff is 2 cm. in length. Catheters of slightly smaller caliber (22 F. or 24 F.) are required for small adults or for patients in whom the larynx seems disproportionately small.

Sterilizing is accomplished by boiling or autoclaving, first removing the rubber sheath and cuff. A new sheath of sterile Penrose tubing can be applied easily each time the catheter is used.

Bronchospirography is most conveniently performed in the fluoroscopic room, provided there is adequate floor space. Premedication for the average adult consists of sodium pentobarbital 0.1 Gm. with atropine sulfate 0.00065 Gm., both given by mouth about one hour before the patient is brought to the fluoroscopic room, nothing having been given by mouth for at least six hours. As the subject sits on the edge of the fluoroscopic table, the pharynx is sprayed lightly several times with 2 per cent solution of Pontocaine Hydrochloride. The larynx, trachea, and larger bronchi are then anesthetized by fractional instillation of 2.0 c.c. of the same solution under mirror guidance, using a Lukens syringe and favoring gravitation into the left bronchus by having the patient incline his body to the left and slightly forward after each instillation.

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*The catheter described was made to specifications by the George P. Pilling and Son Company, Philadelphia.

The catheter is introduced on an appropriately curved stilette under guidance of the laryngeal mirror. Then, with the patient supine, accurate positioning is accomplished under fluoroscopic guidance; entrance into the left bronchus is favored by keeping the tip of the bevel to the left, and by turning the head so that the chin is over the right shoulder. The extreme tip of the catheter should be approximately 4 cm. below the estimated level of the carina.

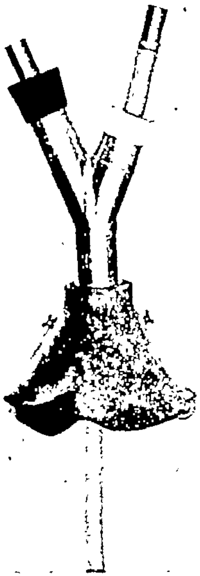

Fig. 2.—Single-lumen catheter method for bronchospirography. After positioning under fluoroscopic guidance and inflation of the distal cuff, the proximal end is brought through the rubber diaphragm partially covering one end of the Y-connector. Echange of air-oxygen mixture to the right lung is maintained around the catheter via the other arm of the Y-connector.

After inflation of the cuff, the lubricated outer end of the catheter is brought through the mask and through the rubber diaphragm occluding one arm of the Y-connector, as shown in Fig. 2 (the rubber diaphragm is a short piece of 3/8 inch Penrose tubing stretched over the end of the arm). The other arm of the connector, through which exchange to the right lung is maintained, is occluded by a rubber stopper through which projects a 5 cm. length of 12 mm. brass tubing. Short lengths of heavy rubber tubing (12 mm. internal diameter, 10 cm. long) are used to make connection with the twin spirometer.

Quiet breathing is recorded for a period of at least four minutes; then one or two determinations of vital capacity are obtained. Finally, maximum breathing capacity[10] is recorded.

RESULTS

Table I shows the data obtained on bronchospirometry using the single-lumen catheter in three subjects with apparently normal respiratory and cardiovascular systems. The percentage of the oxygen consumed by the right and left lungs respectively was found to be 54 per cent and 46 per cent of the total in two of these and 57 per cent and 43 per cent in the remaining case. These values correspond well to the average of 53 per cent consumption for the right lung and 47 per cent for the left lung as given by Jacobaeus[1] for normal subjects.

Table II shows bronchospirometric data comparing the results obtained in five patients with pulmonary disease, in whom determinations were made on separate occasions, first by the double-lumen catheter and then by the single-lumen catheter.

TABLE I. BRONCHOSPIROMETRY IN THREE NORMAL SUBJECTS, USING THE SINGLE-LUMEN CATHETER

PATIENT	PER CENT O_2 USE		RATIO OF TIDAL VOLUMES		
	RIGHT LUNG	LEFT LUNG	RIGHT LUNG		LEFT LUNG
L. C.	54	46	52	:	48
T. O.	57	43	60	:	40
M. L.	54	46	61	:	39

Total oxygen consumption was about the same by the two methods. The division in oxygen consumption between the right and left lungs was identical in two cases and did not differ by more than five per cent in any case, when the two methods are compared. These data suggest that in so far as oxygen consumption is concerned, the results obtained by either method are reliable.

There was no striking difference in the tidal volumes obtained by the two methods. In two patients the rate was greater with the double-lumen catheter and in two it was greater with the single-lumen catheter. In two patients there was a difference of more than 2 in the ventilation equivalents,[3] the lower readings being obtained with the single-lumen catheter. The vital capacities of the individual lungs were slightly greater with the single-lumen catheter.

The most striking difference between the two methods was seen in the measurement of maximum breathing capacity. The capacities obtained using the single-lumen catheter were often more than twice those obtained when the double-lumen catheter was used. Furthermore, the sum of the maximum breathing capacities of the right and left lungs, using the single-lumen catheter method, approached the maximum breathing capacity recorded on external spirometry (Table IV).

The small channels of the double-lumen catheter may at times be partially occluded with bronchial secretions; the disturbance of the ratio of volumes of air moved by the right and left lungs may be considerable. An extreme instance of this was observed in patient 5 with advanced bronchiectasis of the left lung. During the test, the right channel of the double-lumen catheter became partially blocked as evidenced by great diminution in tidal volume; there was no indication of interference with free exchange when the single-lumen catheter was used. Although the percentage distribution of oxygen use between the two lungs did not differ appreciably with the two methods, there was a marked difference between the ratios of tidal air moved by the two

TABLE II. BRONCHOSPIROGRAPHIC DATA: COMPARISON OF RESULTS OBTAINED BY THE DOUBLE-LUMEN CATHETER AND THE SINGLE-LUMEN CATHETER

PATIENT	CATHETER	OXYGEN CONSUMPTION (C.C./MIN.)		TIDAL VOLUME (C.C.)		RATE	MINUTE VOLUME (L.)		VENTILATION EQUIVALENT		VITAL CAPACITY (C.C.)		MAXIMUM BREATHING CAPACITY (L.)	
		R	L	R	L		R	L	R	L	R	L	R	L
V. B. 1	double	140	100	200	150	36	7.2	5.7	5.1	5.7	600	575	9.6	10.4
	single	300	175	300	225	16	4.8	3.6	1.6	2.5	750	710	22.0	11.6
E. J. 2	double	150	125	275	175	24	6.6	4.2	4.4	3.4	700	510	9.8	7.9
	single	150	125	275	240	22	6.0	5.2	1.0	4.2	925	1100	25.2	15.4
G. M. 3	double	300	200	375	225	16	6.0	3.6	2.0	1.8	800	400	6.3	2.0
	single	250	200	275	180	19	5.2	3.4	2.6	1.7	950	525	13.5	7.4
W. M. 4	double	260	175	375	210	15	5.6	3.2	2.1	1.8	1275	800	11.4	8.6
	single	225	150	375	105	21	7.9	3.5	3.5	2.3	1250	650	27.0	11.7
W. G. 5	double	372	50	75	210	33	2.5	0.9	0.7	13.8				
	single	375	75	400	100	22	8.8	2.2	2.4	2.9				

lungs. When the single-lumen catheter was used, the ratio of the volumes of air moved (right:left) was 80:20; the ratio obtained when the double-lumen catheter was used was 26:74, an obviously incorrect finding.

Some of the other results (Table III) suggest that volume distribution ratios obtained by the single-lumen catheter are more accurate than those obtained by the double-lumen catheter. Patient 1, for instance, had minimal bronchiectasis of the superior segment of the left lower lobe. When the double-lumen catheter was used, the ratio of the tidal volume of the right lung to that of the left was 57:43, and the ratio of the volumes of air moved during the maximum breathing test by the right and left lungs was 48:52. On the other hand, the values obtained when the single-lumen catheter was used were comparable for tidal volumes and maximum breathing capacity, namely, 57:43

TABLE III. BRONCHOSPIROGRAPHIC DATA: COMPARISON OF RATIOS (RIGHT : LEFT) OF (A) OXYGEN CONSUMPTION AND (B) VENTILATION, AS OBTAINED IN FIVE CASES WHERE BOTH THE DOUBLE-LUMEN AND SINGLE-LUMEN CATHETERS WERE USED

PATIENT	CATHETER	RATIO OXYGEN CONSUMPTION R	:	L	RATIO TIDAL VOLUMES R	:	L	RATIO MAXIMUM BREATHING CAPACITY R	:	L	LESION
V. S. 1	double	58	:	42	57	:	43	48	:	52	minimal bronchiectasis LLL
	single	63	:	37	57	:	43	60	:	40	
E. J. 2	single	54	:	46	61	:	39	56	:	44	abscess RLL
	double	54	:	46	54	:	46	55	:	45	
G. M. 3	double	58	:	42	62	:	38	76	:	24	bilateral bronchiectasis advanced, LLL
	single	56	:	44	60	:	40	65	:	35	
W. M. 4	double	60	:	40	64	:	36	56	:	44	bronchiectasis LLL
	single	60	:	40	69	:	31	70	:	30	
W. G. 5	double	88	:	12	26	:	74				advanced bronchiectasis LLL
	single	84	:	16	80	:	20				

TABLE IV. MAXIMUM BREATHING CAPACITIES OBTAINED BY EXTERNAL SPIROMETRY COMPARED TO COMBINED MAXIMUM BREATHING CAPACITIES IN FOUR CASES WHERE BOTH THE DOUBLE-LUMEN AND SINGLE-LUMEN CATHETERS WERE USED

PATIENT	CATHETER	MAXIMUM BREATHING CAPACITY (L.) R	L	SUM OF MAXIMUM BREATHING CAPACITIES RIGHT AND LEFT LUNG	MAXIMUM BREATHING CAPACITY OBTAINED BY EXTERNAL SPIROMETRY
V. S. 1	double	9.6	10.4	20.0	37.5
	single	22.0	14.6	36.6	
E. J. 2	double	9.8	7.9	17.7	44.0
	single	25.2	15.4	40.6	
G. M. 3	double	6.3	2.0	8.3	30.0
	single	13.8	7.4	21.2	
W. M. 4	double	11.4	8.6	20.0	25.5
	single	27.0	11.7	38.7	

and 60:40. In another patient (4) with advanced bronchiectasis of the left lower lobe, the double-lumen catheter showed the volume of air moved by the right and left sides to be distributed in the ratio of 64:36 during quiet breathing and in a ratio of 56:44 on effort. When the single-lumen catheter was used, the corresponding volume distribution ratios were 69:31 and 70:30.

DISCUSSION

The limitations of the double-lumen catheter arise chiefly because of resistance offered to flow of the air-oxygen mixture. Resistance to flow of gaseous substances increases as the length of the conducting tube is increased, and varies inversely with the cross-section area. Volume flow through tubes of the same length, at the same pressure, varies directly with the fourth power of their respective internal diameters; an increase of only 19 per cent in the internal diameter will theoretically allow the volume flow to double.

Actual measurements show that, using a respiration schema with alternating pressures of 0 and −14 cm. of water, at a rate of 20 per minute, tidal volume through the 26 F. single-lumen catheter exceeds that through one channel of the adult double-lumen catheter in the ratio of 1.0 to 0.43 (175 c.c. as compared with 75 c.c.).

As a matter of fact, the tidal volumes recorded in determinations made with the double-lumen catheter are often comparable to those obtained when the single-lumen catheter is used. This, however, is accomplished only by obviously increased respiratory effort which establishes a vicious circle in the patient whose reserve is limited by calling for still greater ventilation. In our experience it has been nearly impossible to obtain satisfactory determinations of vital capacity and maximum breathing capacity by use of the double-lumen catheter, whereas these can be rather easily determined when the single-lumen catheter is employed.

The increased respiratory effort induced by stenosis breathing through the double-lumen catheter would perhaps not be objectionable in itself, for it might be regarded as a form of unstandardized "exercise test." However, it would appear that determinations of relative function (particularly ventilatory function) will be more accurate if the apparatus used is such as to allow quiet breathing. Having obtained an estimate of the combined function by external spirometry, it is perhaps valid in many cases to calculate the functional capacity of the separate lungs on a basis of the percentages obtained by use of the double-lumen catheter, even though this entails stenosis breathing. But, ideally, the resistance to flow of the air-oxygen mixture should be equal on the two sides; this would require that the ratio between the cross-section areas of the airways (of the same length) to the two lungs be approximately the same as the ratio between their actual ventilatory capacities, a fator which cannot be predetermined.

Actually, the single-lumen catheter does not provide for cross-section areas proportional to the relative ventilatory capacities of the two lungs. Greater accuracy is realized, however, by increasing both airways to the point where resistance to air exchange is but little more than that observed in normal quiet respiration.

One might predict that the values obtained, if the apparatus used were of the double-lumen type, providing channels of the same size to each lung, would be fairly accurate despite stenosis breathing in cases where the actual ventilation of the two lungs is approximately equal. It might be speculated, however, that the greater the disproportion between the ventilation of the two lungs, the greater will be the error induced by stenosis breathing through channels which, although of the same size, do not allow free inspiration and expiration. Relative ventilation determined in this way would presumably be more in error than the relative figures for oxygen absorption (Table III).

Assuming that the actual ventilation (without apparatus in place) of a patient's left lung is only half that of the right, the effect of stenosis breathing through small channels of identical size would make the ventilation of the left or poorer lung appear a relatively greater percentage of the total, since the narrow breathing channels will restrict exchange on the good side to a greater degree than that on the poor side. Errors in determination of ventilation will obviously be reflected in calculations of the ventilation equivalent. Work is in progress to test the above premise experimentally, and will be reported later.

CONTRAINDICATIONS

Active tuberculous lesions of the larynx, trachea, or left bronchus usually contraindicate an attempt at bronchospirography. In most patients, the condition of the larynx and tracheobronchial tree will have been already determined by mirror laryngoscopy and diagnostic bronchoscopy. Dyspnea of moderate degree is considered a relative contraindication. Nontuberculous lesions of the left main bronchus (stenosis, neoplasm, marked deformity) may interfere mechanically with proper positioning of the tip of the bronchospirographic catheter.

The presence of large amounts of bronchial secretion, hitherto a difficult problem in certain cases, is not in itself a contraindication, and preliminary bronchoscopic aspiration is not required, since secretions may be aspirated directly through the single-lumen catheter immediately before recording; for this purpose, a rubber aspirating tube, No. 14 F., is used.

CONCLUSIONS

1. A single-lumen endobronchial catheter for bronchospirography has been described; when used in conjunction with the "twin spirometer" of Gebauer, this catheter appears to provide a simple and practical method for simultaneous determination of the function of the separate lungs.

2. The method described appears to offer the following advantages: (a) Introduction and manipulation of the catheter are relatively easy; its complete radioopacity facilitates fluoroscopic guidance. (b) Need for increased respiratory effort during the test is avoided by provision of an adequate airway to each lung. (c) It is suggested that elimination of stenosis breathing (lessened resistance to flow of the air-oxygen mixture) will increase accuracy of determinations of relative ventilation of the two lungs, particularly when a marked disproportion exists. (d) Determinations of vital capacity and maximum

breathing capacity for the separate lungs, difficult or impossible with the double-lumen catheter, are rather easily carried out when the single-lumen catheter is employed. (e) In cases where copious or tenacious secretions are troublesome, aspiration through the single-lumen catheter is an important advantage.

3. Bronchospirographic data obtained by the single-lumen catheter method are presented and compared with those recorded when the double-lumen catheter is employed.

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CONTRALATERAL FRACTURE OF FIRST AND SECOND RIBS FOLLOWING THORACOPLASTY

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ISOLATED fractures of the first rib occur very infrequently from any cause. Liberson,[1] in a review of 2,014 cases of rib fractures, found but three instances in which the first rib alone was involved. Since thoracoplasty was introduced for the treatment of pulmonary tuberculosis, innumerable articles have appeared in the literature dealing not only with the effect of the operation on the diseased lung, but also with the various complications resulting from this procedure. A survey of the literature failed to disclose any mention of rib fracture on the *contralateral side following thoracoplasty.* It is the purpose of this paper to present fractures of the first and second rib on the contralateral side subsequent to this operation.

An analysis of 208 consecutive cases of thoracoplasty performed at the National Jewish Hospital revealed fractures of the first rib in six instances and of the first and second ribs in two, making an incidence of 3.8 per cent. Of the total number of thoracoplasties performed, 126, or 60.6 per cent, were done on male patients, and 32, or 39.4 per cent, were on female patients. Four fractures were found in the male and four in the female patients. All the fractures occurred in persons between the ages of 26 and 40, which group comprised 154 of the total number of patients.

CASE REPORTS

CASE 1.—L. K., a man aged 32 years, had an onset of pulmonary tuberculosis with hemoptysis in 1930. Left artificial pneumothorax was instituted in 1931 and continued until 1934. In addition, left phrenicectomy was performed in January, 1934. Right diagnostic pneumothorax was done in 1936, and continued for five months. A left thoracoplasty was performed in three stages (eight ribs) between August and November, 1936. After the second stage the roentgenogram of Oct. 1, 1936, showed a complete fracture in the middle third of the first rib on the right (Fig. 1, *A*). Two years later a thickening was present in the fracture area (Fig. 1, *B*). There was no pain.

CASE 2.—G. V., was a 33-year-old man. Pulmonary tuberculosis was diagnosed in 1938. Several attempts to induce pneumothorax on the left were unsuccessful. A left phrenic crushing was performed in 1939. A left thoracoplasty was done in two stages (six ribs) in 1944. After the first stage (March 17, 1944) a complete fracture of the anterior third of the right first rib was seen on x-ray examination (March 25, 1944) (Fig. 2). There were no symptoms present.

CASE 3.—R. H., a 37-year-old woman, had a history of pulmonary tuberculosis since 1932. Attempts to induce pneumothorax on the left failed. In 1937 a left phrenicectomy was performed, and pneumoperitoneum instituted. Thoracoplasty on the left was done in five stages (nine ribs) in 1938. After the first stage on Aug. 5, 1938, an incomplete fracture

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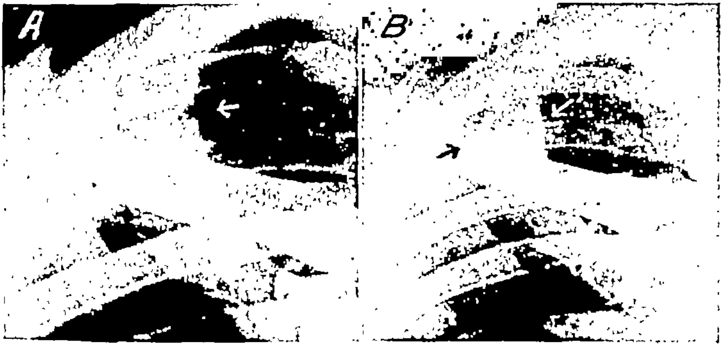
could be seen at the junction of the middle and anterior thirds of the right first rib (Aug. 26, 1938) (Fig. 3, *A*). The roentgenogram of Oct. 20, 1938, showed callus formation in this area (Fig. 3, *B*). The patient had no specific complaints referable to the fracture.

CASE 4.—E. M., a 27-year-old woman, had onset of tuberculosis in March, 1931. Right artificial pneumothorax was discontinued after seven refills as ineffective. Right phrenic crushing was done in September, 1938. A right thoracoplasty was performed in 1940 in three stages (eight ribs). After the first stage on Feb. 27, 1940, the roentgenogram revealed a transverse fracture at the middle third of the left first rib with slight displacement. (March 13, 1940) (Fig. 4). The patient did not complain of pain at the site of fracture.



A. *B.*

Fig. 1.—Case 1. *A*, Roentgenogram showing complete fracture of right first rib. *B*, Roentgenogram taken two years later showing irregularity of right first rib at site of fracture.

CASE 5.—H. L., a man aged 36 years, had onset of pulmonary tuberculosis in 1929. Left phrenic crush was done in 1934. Left pneumothorax which was initiated in 1938 was complicated by empyema. Left thoracoplasty in two stages (seven ribs) was performed in 1946. After the first stage on May 17, 1946, roentgenographic examination revealed a fracture of the middle third of the right first rib (May 25, 1946) (Fig. 5). There were no symptoms due to the fracture.

CASE 6.—B. W., a woman, 28 years old, had onset of pulmonary tuberculosis in 1921. Right phrenicotomy was done in 1929. The first stage of a right thoracoplasty was performed on Dec. 18, 1933 (three ribs). The roentgenogram of Jan. 2, 1934, showed a transverse fracture in the middle third of the left first rib (Fig. 6, *A*). There was displacement of the fragments. Another roentgenogram taken on Feb. 9, 1934, prior to the second stage, revealed, in addition to the fracture of the first rib, a fracture in the middle third of the left second rib (Fig. 6, *B*). A subsequent roentgenogram showed two areas of callus on the second rib, indicating two fractures (Fig. 6, *C*). The patient did not complain of pain in the region of the fractures.

CASE 7.—J. U., a man aged 37 years, had onset of tuberculosis in 1927. Right phrenicectomy was done in 1932. Right thoracoplasty was performed elsewhere in 1936 with removal of second to fifth ribs. Three revisions were performed during 1938 and 1939. The first revision was done Nov. 26, 1938. A roentgenogram taken Jan. 17, 1939, revealed a fracture of the middle third of the left first rib. Slight displacement of the fragments was noted (Fig. 7). The fracture was not present on the immediate postoperative roentgenogram.

CASE 8.—E. M., a woman, 39 years old, had onset of tuberculosis in 1932. Left artificial pneumothorax was maintained from 1933 to 1939. Tuberculosis of the left main bronchus developed, and the lung did not re-expand. A left thoracoplasty was performed in three stages (nine ribs). The first stage was done on March 28, 1941. The first postoperative roentgenogram made on April 1, 1941, was negative for fracture. X-ray examination made on April 14, 1941, revealed a fracture of the right first rib in the middle third (Fig. 8, *A*).

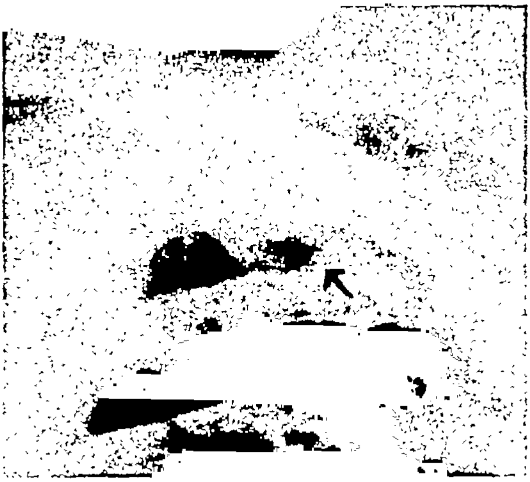
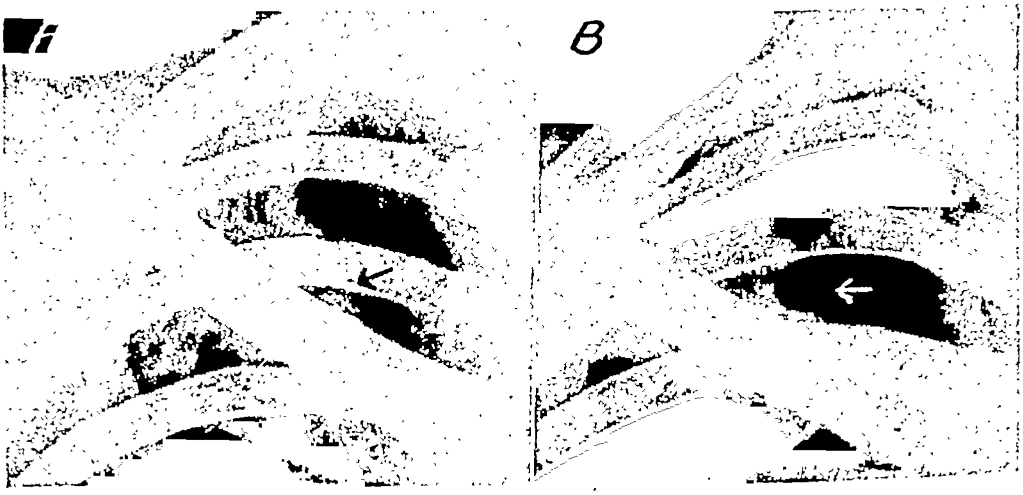


Fig. 2.—Case 2. Roentgenogram showing complete fracture of right first rib.



A. *B*.

Fig. 3.—Case 3.—*A*, Roentgenogram showing incomplete fracture of right first rib. *B*, Roentgenogram taken two months later shows callus formation.

After the second stage (May 2, 1941) an additional fracture in the middle third of the second rib was found on the roentgenogram taken on May 27, 1941 (Fig. 8, *B*). This patient complained of slight pain in her right upper chest after the first stage.

DISCUSSION

Complications following thoracoplasty for pulmonary tuberculosis have been discussed in numerous publications dealing with this subject. None of them, however, mentioned fracture of ribs on the contralateral side. Because of the overlapping shadows in the apical region of the conventional chest roentgenogram, these fractures may be overlooked easily. On the other hand, one must be particularly careful in interpreting a supposed fracture of the first or second rib. Although we considered several suspicious cases, we did not include any instance which did not show a definite fracture or callus formation.

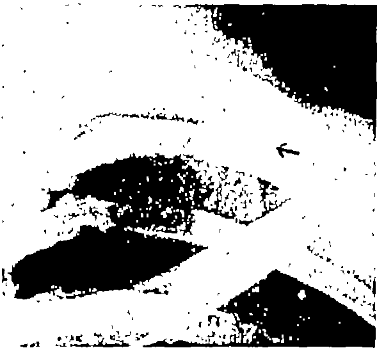


Fig. 4.—Case 4. Roentgenogram showing fracture of left first rib with slight displacement of fragments.

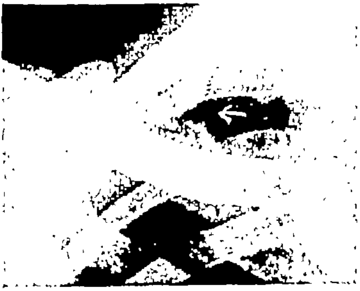
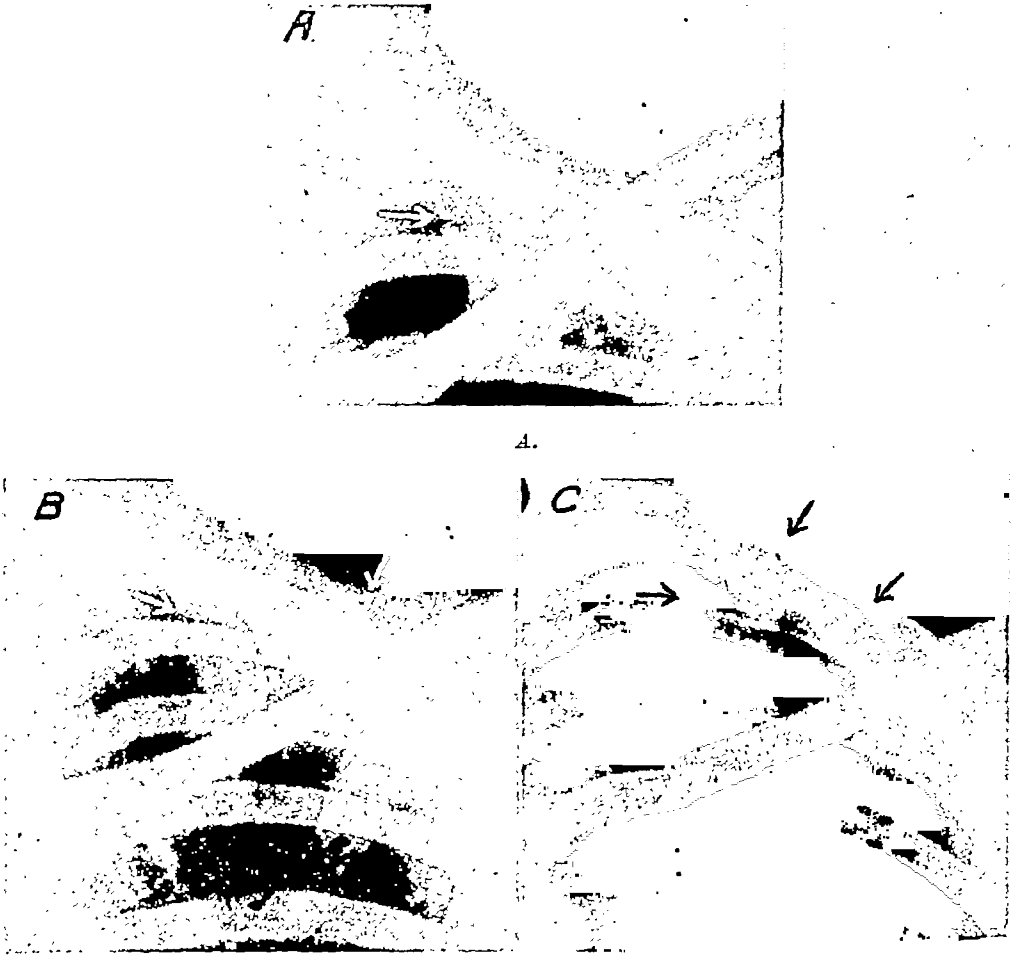


Fig. 5.—Case 5. Roentgenogram showing fracture of right first rib.

The thoracoplasties analyzed in this study were performed by five surgeons. The surgical technique varied with the individual. Postoperative treatment likewise differed. Fractures were found regardless of the surgeon or type of postoperative treatment.

For purposes of classifying the location of the fractures, the first and second ribs were arbitrarily divided into posterior, middle, and anterior thirds. In those cases where fracture of the first rib was found, all but one instance occurred in the middle third. The exception was Case 2, where the fracture was situated in the anterior third. The second rib was fractured in the middle third in both instances.

The fractures were of two types, incomplete and complete. Seven of the eight cases in our series showed a complete fracture. Case 3 was an example of the incomplete variety. There was no displacement of the fragments in four cases. In the remainder, separation of the fragments was found; in two instances the proximal fragment was displaced upward and laterally (Cases 4 and 6), and in one the distal fragment was displaced laterally (Case 7). The fracture line was uniformly transverse. No comminution of the fragments was noted.



A.

B.

C.

Fig. 6.—Case 6. *A*, Roentgenogram showing fracture of left first rib with considerable separation of the fragments. Second rib negative. *B*, Roentgenogram taken five weeks later shows fracture of left second rib. *C*, Roentgenogram taken at still later date shows two areas of callus on left second rib.

The first and second ribs are similar in appearance, but they differ in certain anatomical points from the other ribs. The second rib has a slight angle which is not present in the first rib. The first rib, which is the most curved and the shortest of all ribs, is broad and flat. The upper surface of its body is marked by two shallow grooves; the anterior groove transmits the subclavian vein, the posterior groove the subclavian artery and the lowest trunk of the brachial plexus. The scalenus medius, scalenus anterior, and the first digitation of the serratus anterior are attached to the first rib. The second rib is not flattened horizontally as is the first rib. The first and second digitations of the serratus anterior as well as the scalenus posterior are inserted on this rib (Fig. 14).

The vast majority of fractures are due to a single accidental trauma. Lane[3] believed that isolated fractures of the first rib could result from (a) indirect violence, the force being transmitted through the clavicle, (b) directly by means

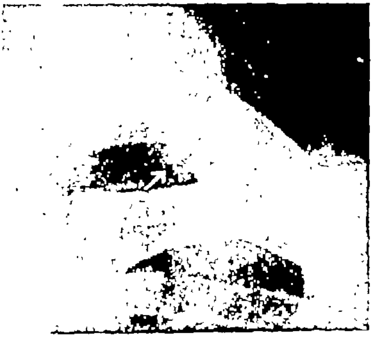
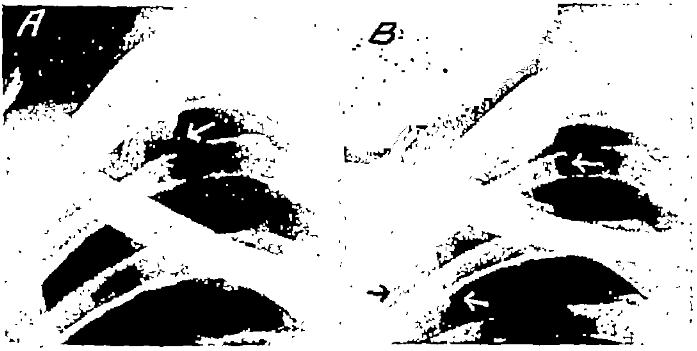


Fig. 7.—Case 7. Roentgenogram showing fracture of left first rib with slight displacement of fragments.



A. B.

Fig. 8.—Case 8. *A*, Roentgenogram showing fracture of right first rib, following first stage thoracoplasty. *B*, Roentgenogram after second stage thoracoplasty showing fracture of right second rib.

of force applied from behind, and (c) by indirect violence, the force being transmitted from the manubrium. There are, however, a limited number of reports in which the fracture was not caused by a single direct injury. These cases have been explained on the basis of muscular pull.[3-10] March fractures of the first rib have been reported.[11] Spontaneous rib fractures other than first or second ribs due to cough have been recorded in tuberculous individuals.[4, 12-14]

These fractures are thought to result from muscular stress. Bond,[14] however, considered decalcification of the ribs and general debility as the etiologic factors rather than muscular contraction.

In the eight cases analyzed in our series we could not demonstrate a single trauma as the etiologic factor. We considered the position of the patients on the operating table as a possibility. In six cases a fracture was found on the first roentgenogram which was taken on the fourth to the fourteenth postoperative day. In one patient (Case 1) the fracture was seen after the second stage. In Cases 7 and 8 the first postoperative roentgenograms were negative, the fracture being first noted in subsequent films preceding the second-stage thoracoplasty. We, therefore, do not believe that the position of the patient on the operating table or the surgical technique employed could be the causes of the fractures.

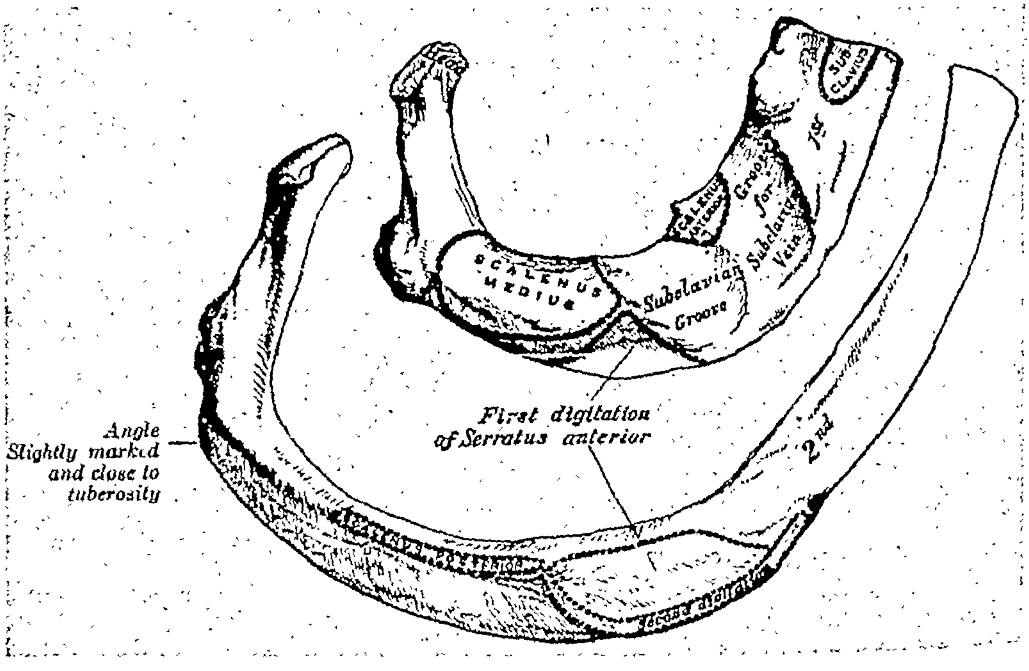

SUB CLAVIUS
1st
SCALENUS ANTICUS
Groove for Subclavian Vein
SCALENUS MEDIUS
Subclavian Groove
First digitation of Serratus anterior
Angle Slightly marked and close to tuberosity
2nd
Second digitation

Fig. 9.—Photograph of first and second ribs. (Reproduced from Gray's Anatomy, ed. 24, 1912, Figs. 118 and 119. Courtesy of Lea and Febiger.)

Isolated fractures occurred in individuals regardless of the type of postoperative management such as shot or sandbags on the operated side, tight strapping of the side of surgery with the adhesive tape being carried across the contralateral shoulder, or special braces to aid collapse and to prevent paradoxical motion.

We assume that removal of ribs during the first stage of a thoracoplasty alters the normal mechanics of those muscles attached to the first and second ribs on the contralateral side. The insertions of the scalenus anterior, scalenus medius, and serratus anterior are released when the first two ribs are removed. Consequently, the pull of the corresponding muscles on the contralateral side is unopposed. Since the fractures do not occur during or immediately after operation, it is presumed that they result from prolonged muscular traction. It is noteworthy that all the fractures with one exception (Case 2) occurred in the area of greatest muscular stress and where the bone structure was thinnest due to the subclavian grooves. This is the region which we arbitrarily classified as the middle third.

Clinically, no symptoms were observed in these patients with one exception (Case 8). There were no complications, such as pressure on the brachial plexus, injury to the contiguous blood vessels, or perforation of the pleura, which frequently occur in fractures resulting from a single trauma. Because these fractures were asymptomatic, no therapy was necessary.

SUMMARY

1. An analysis of 208 cases of thoracoplasty revealed fractures of the first or the second rib, or both, on the contralateral side in eight patients.

2. In seven cases the fracture occurred after the first stage thoracoplasty. The fracture was first observed in one case after the second stage.

3. A theory of etiology is presented.

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PNEUMONOLYSIS FOR THE CURE OF TENSION PNEUMOTHORAX

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In a previous communication[1] pneumonolysis was described as a lifesaving measure in certain types of tension pneumothorax complicating pneumothorax therapy. Others have reported similar experiences.[2]

In this presentation two additional cases of tension pneumothorax cured by pneumonolysis after other measures have been tried and failed are reported. In both instances, the patients were known to have pulmonary tuberculosis but the conditions under which the tension pneumothorax developed were entirely different in each case. In the first patient, tension pneumothorax occurred as a direct complication of pneumothorax therapy, the result of a tear in the visceral pleura at the base of an adhesion which remained attached to lung and chest wall. In the other patient the tension pneumothorax developed in the contralateral or good lung which was not under treatment.

TENSION PNEUMOTHORAX IN THE PRESENCE OF PNEUMOTHORAX THERAPY

Although this complication may follow the initial treatment, it more often occurs weeks or months after the therapeutic pneumothorax has been well established and successfully maintained. Fortunately the complication is not common, occurring in less than one per cent of treated cases.

The relatively rapid introduction of air into the pleural cavity at the time of treatment places pleural adhesions, when present, under sudden tension, with maximal strain at the weakest point—usually the site of attachment of the adhesion to the lung. This sudden strain may force an adhesion to tear itself partially loose from the lung, carrying with it visceral pleura and causing at the same time a small tear in the lung.

With the adhesion remaining attached to the surrounding lung, the perforation is kept from self-closure, and a valve mechanism of the flap variety is set up.[3] Air enters the pleural cavity through the tear, but cannot escape. The resulting increased intrapleural pressure in turn puts greater tension on the adhesion with enlargement of the tear in the lung, and a vicious cycle is set up. If this is not corrected, the increasing intrapleural pressure may result in the death of the patient through exhaustion, infection, and suffocation.

The problem obviously is a mechanical one. The pulmonary tear must be sealed if the patient is to be saved. On the other hand, the pneumothorax should be maintained in order to influence the tuberculous process favorably. Under such circumstances, the intrapleural severance of the offending adhesion is the only logical solution and is lifesaving.

Following the severance of the offending adhesions, the lung retracts, becomes well collapsed, and the tear seals itself automatically. The spontaneous

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pneumothorax is thus permanently abolished and the patient is cured of the complication.

It is important to keep the above sequence in mind, as the problem that presents itself is one of the true emergencies in medical or surgical practice. The relief to the patient following the successful severance of the offending adhesion is one of the most dramatic and satisfying of experiences. An individual, apprehensive and struggling for breath, within a matter of minutes begins to breathe easily and normally, grateful that his life has been somehow miraculously saved.

Pneumonolysis must be employed relatively soon after the development of the valvular pneumothorax because the longer the fistula exists, the greater is the danger of pleural infection and exhaustion of the patient. If offending adhesions are demonstrable in the x-ray, and if it is desirable to maintain the therapeutic pneumothorax, thoracoscopy is indicated. If no operable adhesions are found, the pneumothorax should be abandoned as the complication, even if temporarily corrected, may recur at subsequent refills and may lead to death.

CASE REPORT

Mrs. A. C., aged 21 years, when first diagnosed had exudative tuberculosis with cavity formation involving the right upper lobe and scattered flocculent spots in the remainder of the lung and throughout the middle half of the left lung field. She was acutely ill and her temperature was septic in character with a range of from 98° F. in the mornings to 102.3° F. in the afternoons.

Pneumothorax was started on the right side on Aug. 23, 1945. Numerous adhesions were encountered, some of which were severed on Oct. 11, 1945. However, the remaining adhesions which were proved inoperable by later thoracoscopy prevented closure of a cavity in the apex of the right lower lobe. There was no difficulty, however, in administering the pneumothorax treatment on this side.

In the meantime, the left lung was getting progressively worse and at least four thin-walled cavities could be demonstrated in the film of Dec. 3, 1945. Although the case appeared hopeless, to give the patient whatever chance there might still be in saving or prolonging her life with collapse therapy (streptomycin was not then available), pneumothorax was established on the left side. There was no difficulty in initiating the pneumothorax and no untoward symptoms. She received the first refill the following day and felt fine.

The second refill was on Dec. 8, 1945 (250 c.c. of air). It was also accomplished without difficulty, and apparently everything was satisfactory. A few hours later, however, she complained of increasing shortness of breath, and that night the patient was in acute distress.

Fluoroscopic study revealed marked collapse of the left lung, particularly of the free lower lobe. The upper lobe containing the cavities was incompletely collapsed and several adhesions were seen extending between this part of the lung and the chest wall. (Figs. 1 and 3.) The pneumothorax was greater than could possibly be explained on the basis of the relatively small amount of air introduced therapeutically. It was obvious that the patient had developed a spontaneous pneumothorax on the left side.

After removal of 1,600 c.c. of air, the patient was greatly relieved and again breathed comfortably. About twelve hours later the dyspnea again became acute, and 1,500 c.c. of air had to be removed before the patient was made comfortable. The same process repeated itself twelve hours later and again in six hours, and again in four hours.

It became apparent that the patient had developed a small leak in the left lung and that a flap valve mechanism was involved—one which allowed air to enter the pleural cavity, but prevented its escape. Furthermore, the tear must have gradually increased in size, since the accumulation of air in the left pleural cavity became progressively greater and decompression gave relief for progressively shorter periods, from twelve to six to four hours.

A careful study of the x-ray film (Fig. 1) indicated that the adhesions over the left upper lobe might prove operable. Accordingly, the operation of closed pneumonolysis using the Cutler Thoracoscope was undertaken on Dec. 12, 1945.

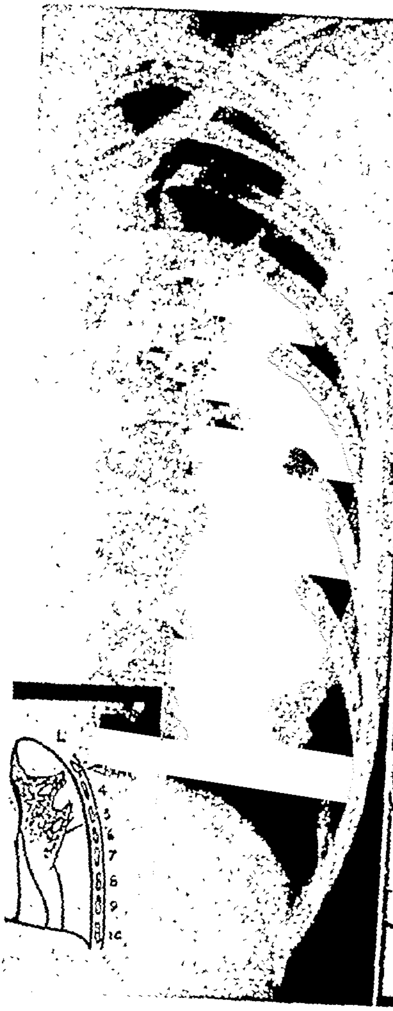

Fig. 1.

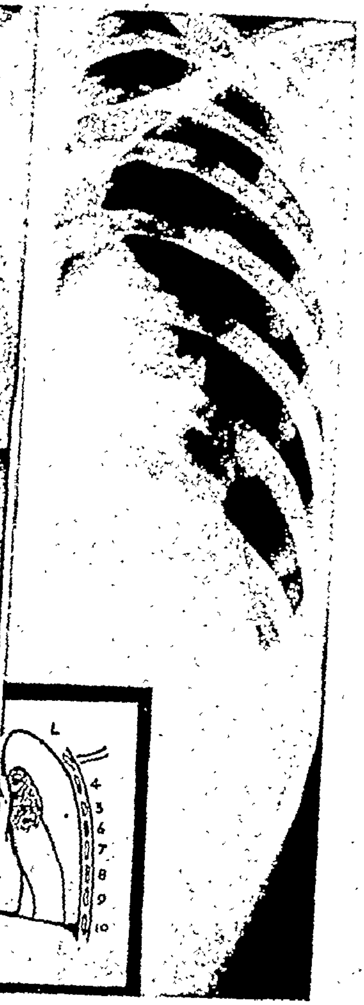

Fig. 2.

Fig. 1.—Case 1. Spontaneous collapse of left lung following second pneumothorax refill. Heart and mediastinum are shifted sharply to right, and the diaphragm is depressed. The upper lobe is kept from greater collapse by adhesions illustrated in Fig. 3.

Fig. 2.—Case 1. Collapse of left lung after closed pneumonolysis with Cutler Thoracoscope. Note good collapse of left lung and marked lessening of tension in pleural cavity. The spontaneous pneumothorax was abolished pneumothorax treatment continued.

A careful search for the point of leakage was unsuccessful. There was no visible break, no large gaping hole. This was also true in the previously reported cases and is readily explainable. A small point of leakage can only be demonstrated under water, as in the case of an inflated punctured tire tube when one can readily locate the puncture by watching the escaping air as it bubbles through the liquid medium; or (2) at post mortem.

While exploring the adhesions with the forceps, it became obvious that the tear in the lung was at the base of the membranous band encountered at the level of the seventh posterior interspace (Fig. 3). In manipulating the blade of the forceps around this

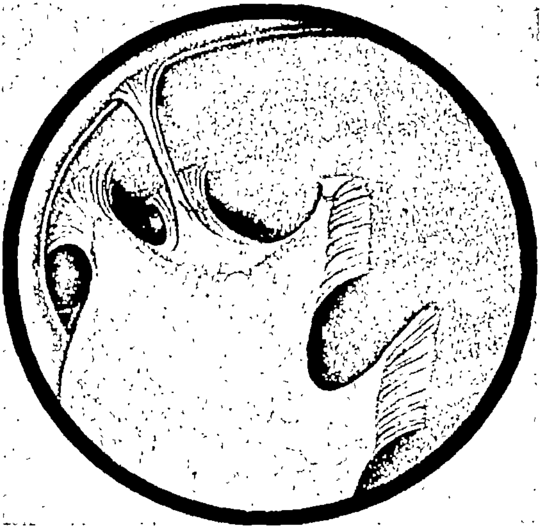

Fig. 3.—Case 1. Conditions in the left pleural cavity as seen through the thoracoscope before severance of adhesions. The perforation in the lung was established at the base of the lower membranous adhesion. For details see text.

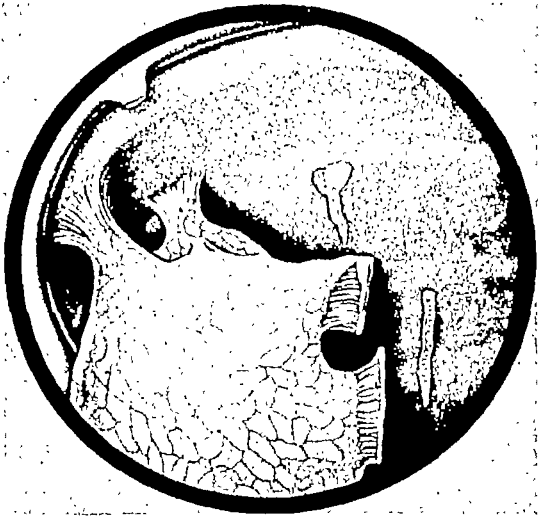

Fig. 4.—Case 1. Conditions in left pleural cavity as seen through the thoracoscope following severance of three adhesions. The patient obtained prompt and lasting relief from the spontaneous as soon as the lower membranous band was severed.

adhesion in preparation for its surgical severance, breathing became noticeably easier and improved remarkably following the cutting. Apparently the placing of the forceps' jaws around the adhesion also covered the break in the lung and following the severance of the adhesion the lung in this region collapsed sufficiently to seal the tear and stop further leakage of air. Short of demonstrating the break at post mortem, this must be regarded as reasonable proof of the mechanism involved and therefore of the rationale of pneumonolysis as a specific remedy in this type of traumatic spontaneous pneumothorax.

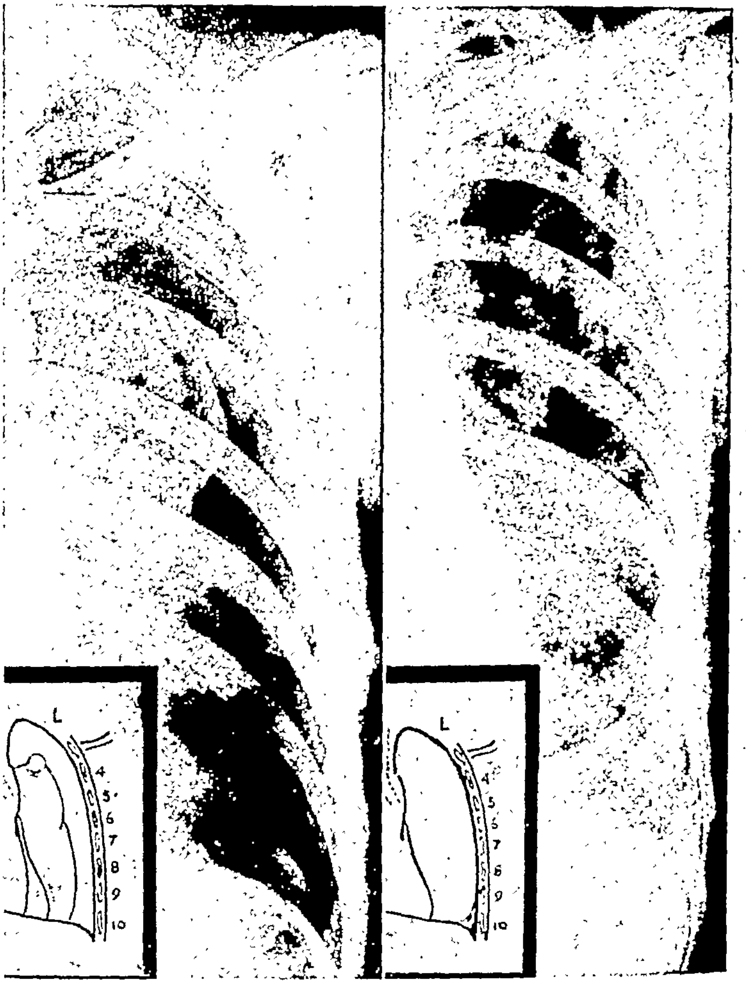

Fig. 5. Fig. 6.

Fig. 5.—Case 2. Tension pneumothorax in left chest in the absence of demonstrable disease in the lung. Annular area of rarefaction at apex believed to be an emphysematous bleb (not proved at thoracoscopy). X-ray taken shortly after decompression with syringe and needle. Note marked subcutaneous emphysema.

Fig. 6.—Case 2. Left lung remains fully reexpanded nine weeks after closed pneumonolysis. No recurrence of spontaneous in interim.

In all, three adhesions were severed. The first was the membranous band already mentioned. The second adhesion was in the region of the fourth posterior interspace. It was short, wedge-shaped, and fibrous, with lung running almost to the chest wall along the upper border of the adhesion. It had to be enucleated with the thoracotome. The third adhesion was a simple cord which extended from the apex of the lung to the subclavian vessels. It was severed without difficulty with the forceps thoracoscope. Part of the apex was found widely adherent to the posterior chest wall in the vertebral gutter. This relationship was not disturbed. (Fig. 4.)

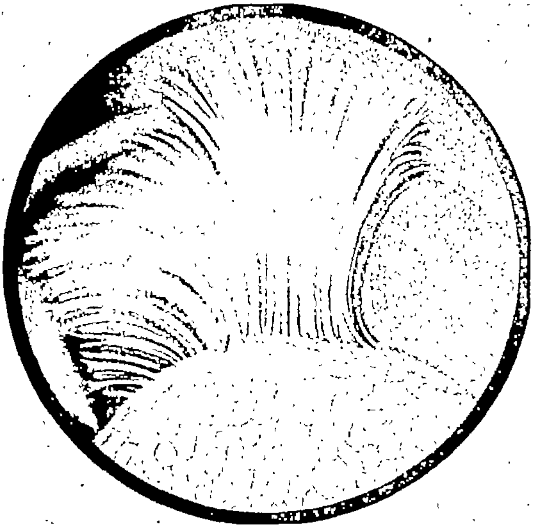

Fig. 7.—Case 2. Conditions in the left pleural cavity as seen through the thoracoscope before severance of extensive adhesion running to second anterior rib and mediastinum.

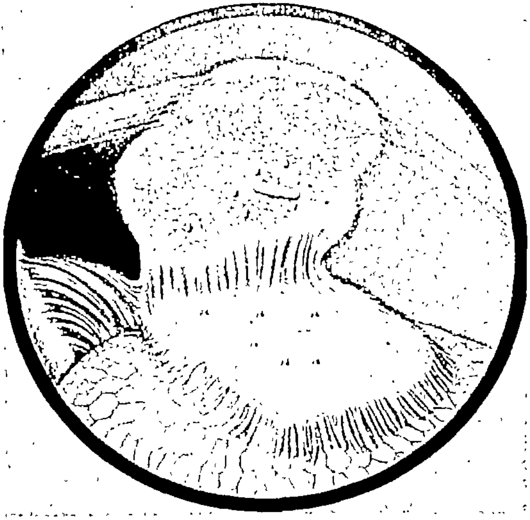

Fig. 8.—Case 2. Conditions in left pleural cavity following severance of wide adhesion shown in Fig. 7. The adhesion had a hollow center containing numerous strings and narrow band adhesions. At the base of one of these strings, in the center of the main adhesion, there was definite dimpling of the lung, as if a small tear were present. No actual break, however, could be demonstrated.

The patient tolerated the operative procedure quite well and remained remarkably free of dyspnea following operation. She obtained a good collapse of the left lung and was relieved of her distressing traumatic spontaneous pneumothorax (Fig. 2). Some time later this patient died of progressive pulmonary tuberculosis.

TENSION PNEUMOTHORAX IN AN APPARENTLY HEALTHY LUNG

Spontaneous pneumothorax is not a rare occurrence in apparently healthy people and not uncommon in the presence of pulmonary tuberculosis. In the latter, it may result from a ruptured emphysematous bleb or from erosion, the result of progressive disease. In either case, the spontaneous pneumothorax may develop into the tension variety and if not cured may lead to death.

In the case to be reported below in a patient known to have pulmonary tuberculosis, it was the "good," contralateral or untreated lung which underwent spontaneous collapse and threatened the life of the patient.

The spontaneous apparently followed the rupture of an emphysematous bleb, but the valve mechanism resulting in the tension pneumothorax was due to subsequent tear of the lung at the base of attached pleural adhesions, the same as in the first case described above.

CASE REPORT

This patient, J. A. aged 38 years, was under pneumothorax treatment for advanced tuberculosis involving the right upper lobe since July 30, 1946, and was apparently doing well. As far as one could tell from routine chest x-ray studies, the left lung was free of disease.

On the afternoon of June 2, 1947, he developed sudden pain in the left or *untreated* side and became progressively short of breath to the point of acute distress. The outlook appeared ominous. A diagnosis of tension pneumothorax was made. Repeated aspirations of air from the left pleural cavity with syringe and needle gave only temporary relief, the intrapleural pressure quickly rising to positive, irrespective of the amount of air aspirated. It was obvious that the spontaneous pneumothorax was complicated by a pleural tear of considerable size.

An intercostal catheter was then inserted into the pleural cavity and continuous underwater decompression instituted. This was kept up for three full days.

The patient obtained definite relief, but as soon as the catheter was pinched off dyspnea returned and became threatening. It became apparent that the pleural fistula would not close under this management. In the meantime, fluid began to form in the pleural cavity and infection of the space and exhaustion of the patient were real dangers.

Careful fluoroscopic study was strongly suggestive of apical adhesions. There was also evidence of what appeared to be an emphysematous bleb at the left apex (Fig. 5). Pneumonolysis was accordingly undertaken on June 2, 1947.

An extensive cylindrical type adhesion was noted running anteriorly from the anterior surface of the left upper lobe to the second anterior rib and first interspace, merging mesially with the mediastinum (Fig. 7). The adhesion first appeared solid, but on severing the axillary border one entered a free space. As the wall of the adhesion was released, numerous strings and small bands were seen. At the base of one of these strings, in the center of the main adhesion, there was definite dimpling of the lung as if there was a small tear present. On careful examination, however, one could not demonstrate a break. The string and band adhesions were severed with the Cutler forceps and the main adhesion resected almost to the mediastinum with the thoracotome (Fig. 8).

Following operation the patient obtained gratifying improvement in his dyspnea. As a precaution, the intercostal catheter was allowed to remain in the pleural cavity and underwater decompression was maintained. Upon blocking the catheter, however, there was no recurrence of dyspnea. The lung gradually reexpanded and the catheter was removed (Fig. 6). The patient is cured of the serious spontaneous pneumothorax which failed to respond to other measures.

SUMMARY

Tension pneumothorax is always a serious complication requiring emergency treatment. Primarily it is a symptom complex occurring in individuals with a variety of lung pathology or with no demonstrable disease.

In this report, emphasis is on life-threatening tension pneumothorax which can be treated successfully by pneumonolysis after other measures fail. Two patients are reported cured by this procedure.

In one patient, tension pneumothorax occurred as a direct complication of pneumothorax therapy for pulmonary tuberculosis. In the other, also a known tuberculous individual, it developed on the "good" or untreated side with no demonstrable disease present in the lung, probably the result of a ruptured emphysematous bleb. In both instances the valve mechanism resulting in the tension pneumothorax was the same, namely, tear of the lung at the base of an adhesion with the adhesion remaining attached to the lung and chest wall.

When the offending pleural adhesion remains attached to the lung and prevents self-closure of the tear, pneumonolysis has proved itself a specific surgical procedure for abolishing the complication. Once the offending adhesion is severed, the lung retracts, the tear seals itself automatically, and the patient obtains immediate and lasting relief.

In the presence of therapeutic pneumothorax, treatment to control the tuberculosis may be continued with safety once the offending adhesions are out of the way. If no operable adhesions are found at thoracoscopy, however, the pneumothorax should be abandoned, as the complication, even if temporarily corrected, may recur at subsequent refills and may lead to death.

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MYOBLASTOMA OF THE BRONCHUS*

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ABRIKOSSOFF,[1] in 1926, described a type of neoplasm which occurs chiefly in immediate relation to striated muscle and which is composed of its embryologic precursors, the myoblasts. There have been many instances of such a tumor, now known as the myoblastoma, reported in the literature since then. Of the cases previously reported, with their diffuse distribution over the body, there has been only one of the bronchus, that reported by Kramer[2] in 1939. A case which has recently come under our observation is reported because of its rarity and the difficulties which may be encountered in the diagnosis of this type of neoplasm.

REPORT OF A CASE

A 48-year-old white man was admitted to Birmingham Veterans Administration Hospital on July 17, 1946, with complaint of a draining sinus of the right thoracic wall, posterolaterally, of six years' duration. He had apparently enjoyed good health working as a grocer and salesman until 1938, at which time he was hospitalized for pneumonia at the Veterans Administration Hospital, Los Angeles. Following his discharge, he was troubled with intermittent bouts of fever and chills until his hospitalization again in December, 1939, for a recurrent pneumonitis, right base. In February, 1940, a rib resection, ninth rib posteriorly, was done for drainage of a localized empyema and a lung abscess. Bronchograms revealed multiple abscess pockets and bronchiectasis in the right lower lobe. On Nov. 4, 1940, a right lower lobectomy was performed at San Fernando Veterans Administration Hospital. Microsections revealed chronic multiple lung abscesses with regenerative epithelial areas. The patient developed a bronchopleural fistula and had persistent blood-tinged mucous drainage from a sinus tract in the right seventh interspace posterolaterally. He was discharged in October, 1941, and during the following year was hospitalized on two separate occasions for exacerbation of cough and increased bloody drainage from the sinus tract. In June, 1943, he was again hospitalized, this time because of fever and foul drainage from the sinus. Repeat bronchoscopies revealed a mass in the right main-stem bronchus filling the entire lumen, and on biopsy at another hospital this was interpreted as being chronic granulation tissue with no evidence of malignancy. An attempt was made to obliterate the bronchopleural pulmonary sinus by plastic operation on Nov. 8, 1943, but was unsuccessful. He showed clinical improvement on instillation of penicillin solution into the

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cavity, and was discharged from the hospital in September, 1944, and readmitted three days later because of hemoptysis. This subsided with bed rest; the patient was observed for some time and was discharged in November, 1944. He was admitted to Birmingham Veterans Administration Hospital on July 17, 1946, because of moderate hemoptysis and a persistent hemorrhagic and purulent drainage from the sinus tract.

Course in Hospital.—On admission, physical examination was essentially negative except for a draining sinus in the right seventh interspace posterolaterally, from which there was a moderate amount of purulent secretion. Bronchoscopy revealed an obstruction of the right upper lobe bronchus by an old blood clot and granulation tissue at the carina and in the right main bronchus. The histologic features of the biopsied specimen were interpreted by another pathologist as histiocytic proliferation in association with lipoid deposition. Bronchoscopy was repeated on seven different occasions, a small amount of tissue being removed each time. The sinus tract was treated with injections of penicillin jelly and the drainage showed fluctuations in amount and consistency. Repeated sputum examinations were negative for acid-fast bacilli. The patient's general condition was excellent; he was afebrile and felt well. X-rays of the thorax revealed the lower half of the right lung field obscured by an homogeneous density which represented thickened pleura. The upper half of the right lung was clear. There was an old resection of posterior segments of ribs on the right from the fifth rib down with marked reparative changes. The left lung was clear. On the last bronchoscopy done, Feb. 5, 1947, a tumor mass was seen just below the bifurcation of the trachea in the right main-stem bronchus about one centimeter from the carina and partially filling the bronchus. The upper lobe bronchus was not visible. Two specimens were taken with punch forceps. Microscopic section revealed a tumor composed of large elongated syncytial bands and large round cells having a characteristic structure. The syncytial bands were well delimited from each other. They had an ample, pale, bluish-staining, finely granular and vacuolated cytoplasm and small, round to slightly oval, dark-staining nuclei. The nuclei were fairly regular and there was no evidence of malignancy in these sections.

The morphology of these syncytial bands resembled undifferentiated striated muscle fibers. The clumps of tumor cells were embedded in a cellular stroma. The stroma cells, in places, varied somewhat in size. There were moderate amounts of collagen separating the clumps of tumor cells. There was an overlying intact bronchial mucosa beneath which was a layer of smooth muscle cells. Adjacent to the large granular cells there were bundles of fusiform cells which also resembled undifferentiated myoblastic elements. The nuclei of these cells varied distinctly in size and occasional mononuclear and multinuclear giant cells were seen which appeared to be of myogenic origin. The specimen was interpreted as a myoblastoma of the bronchus.

Planigrams (Fig. 1) taken shortly after bronchoscopy showed a large tumor mass 3 by 4½ cm., projecting from the hilum into the main right bronchus about 1½ cm. distal to the bifurcation, narrowing its lumen to about one-fourth its normal caliber. The origin of the upper lobe bronchus was not obstructed. Fluoroscopic examination with barium revealed no evidence of abnormality. The esophagus was neither constricted nor displaced. Planigrams with barium in the esophagus revealed no connection of the right mediastinal mass with the esophagus.

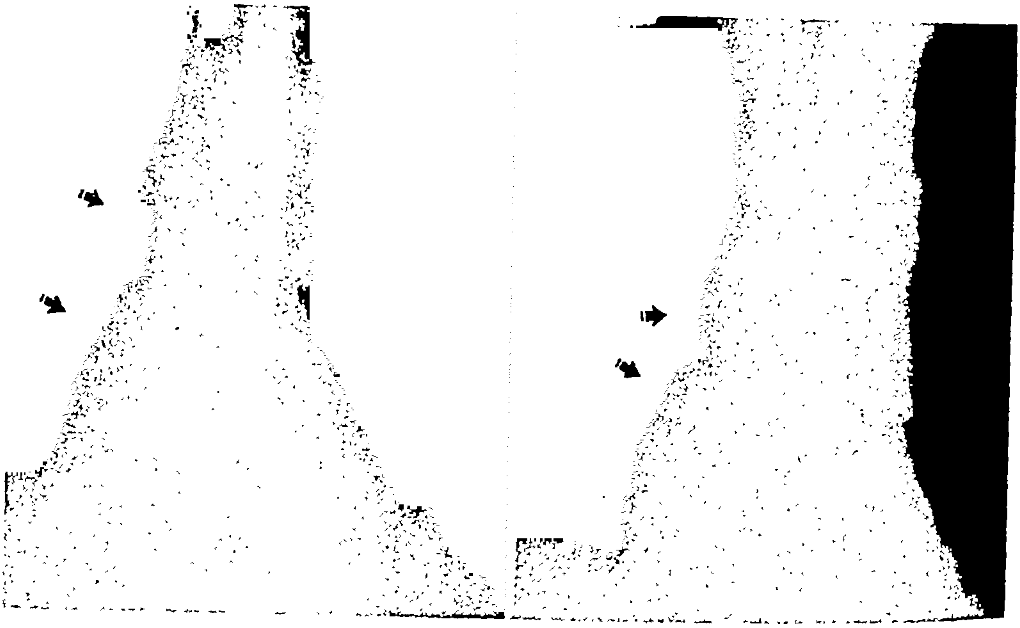

Fig. 1.—Planigrams taken at 7 and 7.2 cm. from the posterior chest wall, showing the location of the tumor.

On Feb. 21, 1947, a right pneumonectomy was performed. Resection of the right upper and middle lobes (Fig. 2) was carried out through an anterior transverse incision made over the fourth rib, extending from the sternum laterally to the midaxillary line. Freeing of the lung and tumor was unusually difficult because of firm adhesions. Due to excessive blood loss, the patient received ten pints of blood while on the operating table. His condition following surgery was good.

On the day following operation, the patient was unable to move both lower extremities. There was some motion in the left foot and good tone of muscles around the ankle but not around the knee. Deep reflexes were absent except for slight motion on the right patellar reflex. The abdominal reflexes were absent, and the cremasteric were present. There were no pathologic toe signs. Vibratory and light touch were present and there was hypesthesia to pin prick up to D8. Circulation was good. There was no evidence of any organic etiology and it was felt that the patient was suffering from a mild hysteria. Within the course of the following few days, movement gradually returned. The patient appeared to be getting along well and was making an excellent recovery. At no time following surgery was there any evidence of a peripheral thrombosis. On March 4, 1947, on the eleventh postoperative day, the patient had what appeared to be a pulmonary embolus and expired. Postmortem examination could not be obtained.

Pathology Report.—The specimen consisted of a right lung including only the upper and middle lobes. The lower lobe had been previously resected and the stump of the main bronchus for the lower lobe was embedded in dense hyaline scar tissue at the hilus. The entire hilus was the site of an irregular patch of dense scar tissue 2 by 3 cm. in dimensions, in which were embedded the main blood vessels to the lobe. Attached to this scar tissue there was a large tumor mass which occupied the entire hilar area of the lung. The tumor was 6 by 5 by 3½ cm. in dimensions. Most of the tumor filled and distended the main bronchus of the right lung. It formed a rounded mass whose surface was fairly smooth and well delimited. The mass, which was of firm consistency, protruded into the adjacent lung parenchyma for a distance of 1½ cm. The cut surfaces had an homogeneous yellow-gray color and coarsely trabeculated appearance. A small patch of hemorrhage occupied the upper pole. The tumor could be separated from the adjacent bronchus throughout most of its extent, but along its lower pole it had broken through the bronchial wall posteriorly, so that a portion of it 1½ by 1 centimeters in dimension was found in the lung parenchyma. The lung itself was firm. The pleura was thickened everywhere by interstitial fibrosis. The cut surfaces were dark red-

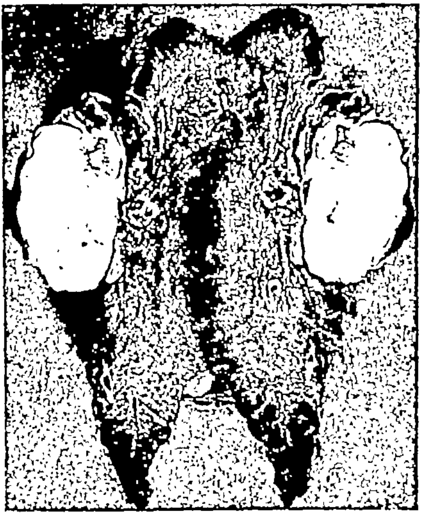

Fig. 2.—Photograph of the tumor and the resected upper and middle lobes of the right lung, showing the tumor occupying the right main-stem bronchus.

brown and granular. The hilar lymph nodes were small and anthracotic. The smaller bronchi were distended and filled with purulent material. Microscopically, the tumor was composed of three elements (Fig. 3): (1) Characteristic large cells which resembled undifferentiated striated muscle fibers. They had foamy, vacuolated, and granular cytoplasm and small, round to oval, dark-staining nuclei. These cells usually formed long bands arranged in groups and layers. Occasionally they formed syncytial masses. Heidenhain iron-hematoxylin stains showed the granular structure of the cytoplasm to be arranged in parallel rows, resembling rudimentary cross striations. (Abrikossoff[1, 3] reported them in two of his cases.) Stains for glycogen were negative. (2) Clumps of elongated cells closely resembling smooth muscle cells, whose elongated nuclei had a fine chromatin network, rounded ends, and nucleoli, and whose cytoplasm was composed of longitudinal myofibrils. The nuclei of these cells varied in size somewhat but there was no evidence of malignancy. These cells formed prominent clumps which intermingled with the large cells described above. (3) Scattered large cells (which were smaller than either of the two above types) whose ample cytoplasm contained an abundance of deeply eosinophilic granules. These cells tended to be elongated and had oval, dark-staining nuclei. They bore no resemblance to eosinophilic leucocytes or myelocytes, but appeared to be a variety of the second type of cell described above.

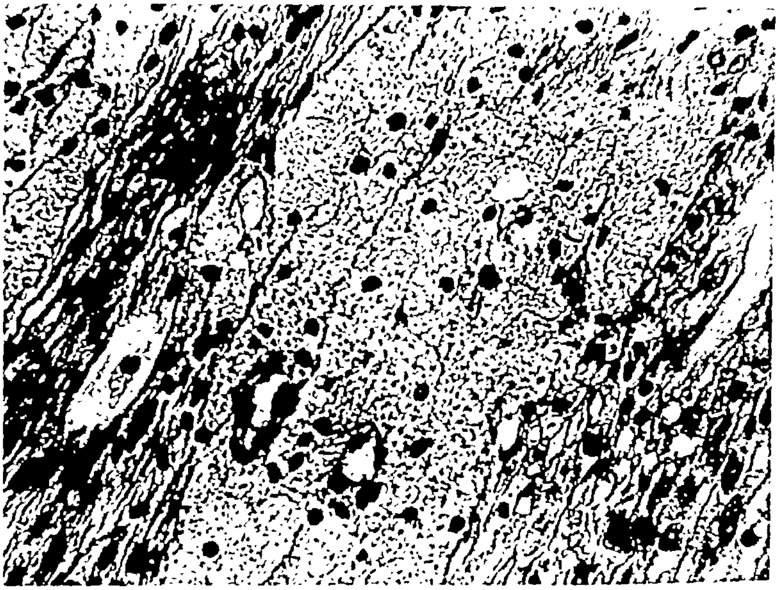

Fig. 3.—Photomicrograph (magnification ×250, hematoxalin and eosine) showing the characteristic large cells with the foamy, vacuolated and granular cytoplasm and small, round to oval, dark-staining nuclei, as well as clumps of fusiform cells.

The adjacent bronchus was not invaded by the tumor. The hilar lymph nodes showed only anthracosis; there were no eosinophilic leucocytes in their sinusoids. The lung parenchyma distal to the tumor was somewhat atelectatic, the alveoli contained recent hemorrhage, and the alveolar walls were thickened by hyperemia and some fibrosis.

Discussion.—Misinterpretations in diagnosis are frequently encountered, even though the histologic characteristics of such tumors seem to be well agreed upon. In one of the first biopsies obtained on bronchoscopy in our case report, the specimen was interpreted elsewhere as histiocytic proliferation in association with lipoid deposition. This was suggestive of the presence of a foreign body (such as suture material), and on the basis of this, repeated bronchoscopies were done in an attempt to locate and remove the suspected foreign substance. These first microsections when reviewed after the last biopsy was obtained, showed them to be similar in appearance, with the characteristic syncytial bands, and with a finely granular and foamy vacuolated cytoplasm and small, round to oval, dark-staining nuclei.

No attempt is made here to discuss in detail the various theories relative to the occurrence of these tumors. As Klinge[4] pointed out, the occurrence of the tumor in regions where no striated muscles appear, can be explained on a dysontogenetic basis; namely, that such tumors arise from retained or misplaced primitive myoblasts which failed to develop into adult muscle tissue. Abrikossoff,[1] in reporting the first cases of myoblastoma, interpreted the tumors as arising from primitive muscle cells which developed in an attempt to repair a degenerative process following some injury or inflammatory process, and not from embryonal cell rests. This was also suggested by Meyer[5] and by Roffo[6] in 1933. Gander[7] and Gray and Gruenfeld[8] were of the opinion that tumors arising in these locations were not histogenetically identical with granular cell tumors arising within skeletal muscle. Abrikossoff, however, later agreed that myoblastoma arising in an area that is devoid of striated muscle might originate from primitive myoblasts representing an embryologic rest. The majority of investigators regard all of these granular cell tumors as of myoblastic origin.

The identification of the characteristic tumor cells as the ancestral cells of striated muscle is strongly suggested by the granular cytoplasm as well as by the presence of the ribbonlike syncytial masses. These latter, according to Godlewski[9] imitate the early embryonal evolutionary phase of the muscle fibers.

Abrikossoff[1] originally classified myoblastomas into four main groups:

1. Tumors composed of myoblasts completely devoid of striations: these are the pure myoblastomas.
2. Tumors with myoblasts similar to those in Group I but showing infrequent longitudinal or cross striations or both, only imperfectly developed in the margins of the cells.
3. Tumors with hypertrophic myoblasts some of great size, frequently multinucleated and of syncytial type. Striation may or may not be present. When it is present, it is usually found in the peripheral zone of cytoplasm.
4. Atypical myoblastic sarcoma, a polymorphous-celled tumor, in some areas frankly sarcomatous, in others showing more highly differentiated cells with well-defined longitudinal and cross striation.

The tumor described here would fall into Group III of Abrikossoff's classification.

SELF-RETAINING SCAPULA RETRACTOR FOR THORACOPLASTY

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THE advantages of self-retaining scapula retracting in thoracoplasties, especially in the first stage, have been discussed in a previous publication.[1] The principle of obtaining countertraction by the use of a rib was established. It was shown that any of the conventional rib spreaders could be used as a self-retaining scapula retractor so long as the assistant kept the retractor blade from slipping upon the scapula. Furthermore, it was suggested that a specially prepared retractor blade would prevent slipping of the retractor on the scapula.

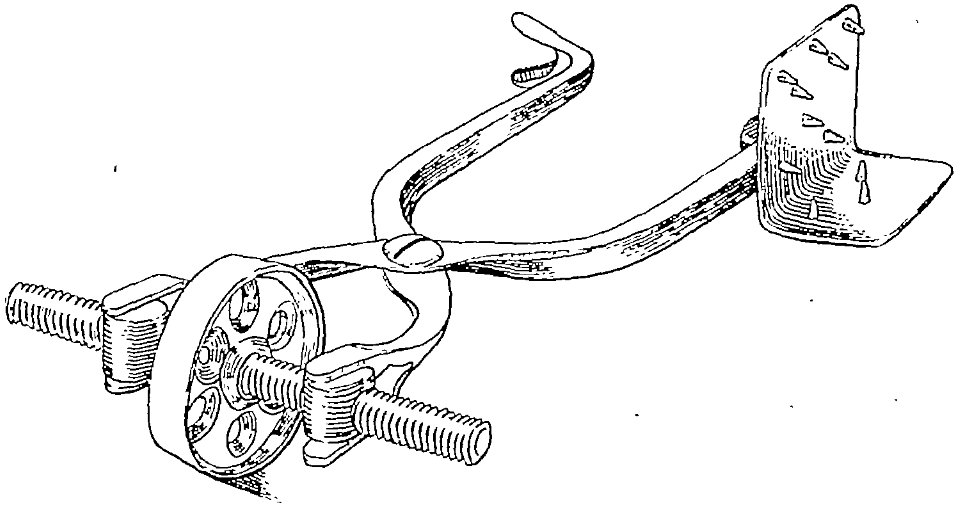

Fig. 1.—The self-retaining scapula retractor shows the mechanism for opening the retractor blades. This mechanism can be used for either the right or left side. There is a small Y-shaped retractor blade for application to the rib which is used for countertraction. The blade presents an edge and a wedge effect upon the rib, thus preventing slipping on the rib. It can be used right or left without adjustment. The larger blade is applied to the scapula covered with its muscles. The pegs in the blade prevent it from slipping. The blade is reversible, permitting its use on either the right or the left side. The mechanism of adjusting the blade is illustrated in Fig. 2.

Many thoracic surgeons have asked for a special retractor designed for self-retaining scapula retracting. A scapula retractor which would not slip, would free both hands of the assistant. If no assistant surgeon were available, it would permit the operator to work efficiently, assisted only by a nurse. Klassen[2] objected to using the ordinary rib spreaders and claimed that the pleura was punctured on many occasions. Puncturing of the pleura has not occurred in the experience of the authors. Klassen designed a special retractor adapted from a Tuffier rib spreader. A right and a left instrument are needed. If an instrument must be modified, an entirely new one may as well be designed.

From Department of Surgery, School of Medicine, University of Maryland.
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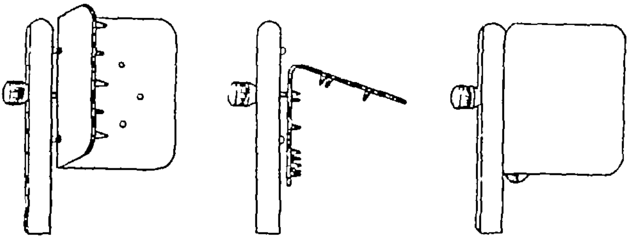

1 Loosening Screw Releases Retractor blade

2. Turn Retractor blade

3 Set Retractor blade and tighten screw

FIG. 2.—The large retractor blade for application to the scapula must be turned 180 degrees to permit the instrument to be used on either the right or left side. The blade is held in place by a screw and two pegs that fit into holes in the retractor blade. The pegs and holes in the retractor blade make it unnecessary to depend upon the screw alone to hold the blade in the proper position. *1*, The screw is loosened, thus releasing the retractor blade. *2*, The blade is being rotated. It is not necessary to remove the screw. The instrument does not come apart and, therefore, it is easily adjusted without dropping parts. *3*, The retractor blade has been rotated 180 degrees and the screw tightened, thus setting the blade for the opposite scapula.

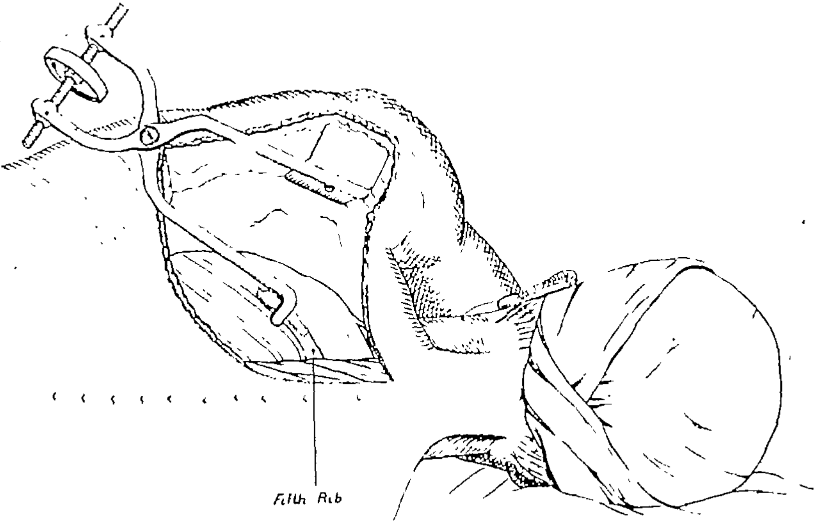

FIG. 3.—The application of the self-retaining scapula retractor to the first stage of a standard type of thoracoplasty on the left side. The fifth rib is used for countertraction. The small blade is applied to the fifth rib about two inches lateral to the lateral margin of the iliocostalis dorsi muscle after subperiosteally freeing a distance of about one inch on the upper and inner surfaces of the rib. The larger blade is applied to the scapula covered by its muscles.

It is superfluous to describe the new self-retaining scapula retractor, since it is so adequately shown in the drawings (Figs. 1, 2, and 3). The use of a new type of mechanism for opening the blades of the retractor and an adjustable blade to fit the scapula permit the instrument to be used on either the right or the left side.

For the instrument to function most efficiently the upper extremity should be extended above the head on the side of the thoracoplasty. The fifth rib is used for countertraction when doing the first stage of a standard type of thoracoplasty. The blade that is to be applied to the rib should be placed about two inches lateral to the lateral edge of the iliocostalis dorsi muscle after subperiosteally freeing a distance of about one inch on the upper and inner surfaces of the rib. Upon completion of the operation this area should be swabbed with 10 per cent formalin so that irregular bone regeneration will not interfere with removal of the rib at the second stage of the thoracoplasty. Gauze should not be used beneath either blade of the retractor, since it promotes slipping.

In practical use the instrument has not slipped out of position. Since the assistant need not hold the retractor, his attention can be directed solely to aiding the surgeon. The pleura has not been entered or punctured by the instrument. The exposure obtained is greatly increased over other methods even to the extent that it is well to warn against dissecting tissue too far anteriorly because it is easy to carry the operation further anteriorly than is necessary. The retractor also has been found extremely useful when doing a revision type of thoracoplasty.

CONCLUSIONS

An efficient self-retaining scapula retractor has been presented.

The instrument described is manufactured by Mr. E. Hydemann of the Baltimore Instrument Co., 1010 Ridgely St., Baltimore, Md.

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WAR WOUNDS OF THE ESOPHAGUS

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WOUNDS of the esophagus have been infrequently treated by military surgeons. Because of the close proximity of the organ to the trachea, the great vessels of the neck, and the thoracic aorta, esophageal wounds are often associated with other injuries causing sudden death. Only rarely, therefore, have soldiers with esophageal wounds reached even the most advanced medical installations. Turner[23] wrote that injuries of the esophagus in war were rare and that there were few records of cases in which the esophagus has been involved and fewer still in which it has been the only organ injured. Euthall[7] observed one cervical esophageal wound among 8,000 patients admitted to a casualty clearing station during World War I. Esophageal wounds are not mentioned in the official American[24] and British[10] medical histories of World War I. The standard German military surgery texts of Franz[9] and Borchard and Schmieden[3] contain scant notice of the esophagus. Edwards,[6] in an excellent review of thoracic injuries, did not mention esophageal wounds. A study of this subject by review of the literature is difficult because of the scarcity and the obscurity of reports. One case of Turner[22] was originally included in a report on gunshot wounds of the urinary bladder.

Wounds of the cervical esophagus have been more frequently described than those of the thoracic portion. Bergheimer[2] collected thirty-one cases of bullet wounds of the cervical esophagus and reported an additional fatal peacetime case from Madelung's clinic. Doubts as to the authenticity of some of these collected cases have been cast by Madelung.[17] Six fatal cases of wounds of the cervical esophagus have been reported by Berger,[1] Euthall,[7] Madelung,[17] and Zeller[25] during World War I. The deaths were due to mediastinal, pleural, and pulmonary suppurative processes. Haecker[13] described the death of a soldier, whose neck had been crushed in an automobile accident during the first German campaign in Poland of 1939. He believed that the esophagus had been perforated by a vertebral transverse process.

Madelung[17] attained a cure of a lacerating bullet wound of the cervical esophagus; the wound was explored and a tube, which was removed eight days later, was introduced into the stomach through the laceration. Jensen[15] operated upon a child, whose esophagus had been perforated by a sled runner, within 2.5 hours of the injury. He drained the cervical wound and passed a duodenal tube through the nose. The tube was removed in eleven days; the child made a complete recovery. Miscall and Harrison[18] reported the remarkable cure of a patient with a tracheoesophageal fistula and a mediastinitis following a cervical wound. It was necessary to perform a tracheotomy, a partial

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thyroidectomy, drainage of the abscess, and, finally, a plastic closure of the fistula with the interposition of neighboring soft tissues between the trachea and the esophagus.

A patient operated upon by Drash[5] in an evacuation hospital illustrates the association of vascular and esophageal injuries. The patient was admitted with a small penetrating shell fragment wound of the neck and a good sized hematoma. At operation a small perforating wound of the carotid vessels at the bifurcation of the common carotid artery required ligation of all three vessels. The small shell sliver, which had penetrated the esophageal wall into the lumen, was removed and the wound closed with a fine suture. The patient recovered.

Two instances of esophageal wounds occurred among 511 patients admitted to a thoracic surgery center* in England during 1944-1945. One case involved the cervical and the other the thoracic esophagus.

CASE 1.—A 25-year-old soldier sustained a penetrating shell fragment wound of the left hemithorax Dec. 24, 1944. The same day the wound of entry was debrided; a needle with flutter valve was inserted into the pleural cavity to control tension pneumothorax. Roentgenograms demonstrated that the missile lay at the base of the neck. December 28 a left thoracotomy was performed by Maj. Irving Sarot, Medical Corps, who found a laceration of the superior mediastinal pleura but was unable to reach the fragment. Jan. 1, 1945, a left cervical incision was made, and the missile was removed by Major Sarot from a position adjacent to the esophagus. An empyema developed, which was drained and packed after resection of a long length of the most dependent rib. Penicillin, 4,050,000 units, was given intramuscularly December 24 to January 16. The seriously ill patient was admitted to the center January 26. The empyema was draining through an incision parallel to the resected rib. Roentgenograms demonstrated a superior intrapleural fluid and air pocket. Iodized oil was injected into this pocket after aspiration of pus. Roentgenograms then showed that the superior pocket communicated with the inferior empyema space and the drainage site by a narrow track. January 29 the superior pocket was dependently drained by resection of the fourth rib through an axillary incision. The suspected bronchopleural fistula was then found. Liquids taken by mouth appeared in part in the new wound. A nonhemolytic *Staphylococcus aureus* and a bacillus of the colon aerogenes group grew in cultures planted from the pus. The patient progressively improved following the empyema drainage. The esophageal fistula healed February 7. The bronchopleural fistula and the two empyema pockets closed later. The patient was transferred on walking status to the United States May 9.

Wounds of the thoracic esophagus have been considered more serious than those of the cervical portion. Gordon-Taylor[12] stated, "The story of wounds of the esophagus is not unnaturally dispiriting," in writing concerning abdominal wounds. The serious complication of accompanying vascular injury is illustrated by a patient of Madelung,[17] who died of erosion of the aorta seventeen days following a penetrating shell fragment wound of the thorax; there was an associated esophageal laceration. Rasumswoski[19] cured a patient with a wound of the thoracic esophagus by drainage of the associated mediastinal abscess.

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*140th General Hospital.

During World War II, Fish[7] had the opportunity of operating, shortly after injury, on a soldier whose thoracic esophagus had been perforated by a bullet during training. The missile had lodged against the trachea. The esophagus was exposed through an extrapleural approach. The bullet was removed, the esophageal wounds were closed with catgut sutures, and the operative wound was drained. The patient recovered after a stormy course complicated by atelectasis, mediastinitis, and hemothorax. A tracheotomy was required during the postoperative period. Burbank, Falor, and Jones[4] reported that three wounds of the thoracic esophagus were sutured among 374 thoracic wounds treated by the personnel of an auxiliary surgical group. Their cases of esophageal wounds were not described, but they were probably not so severe as that of the patient treated by Fish.[7]

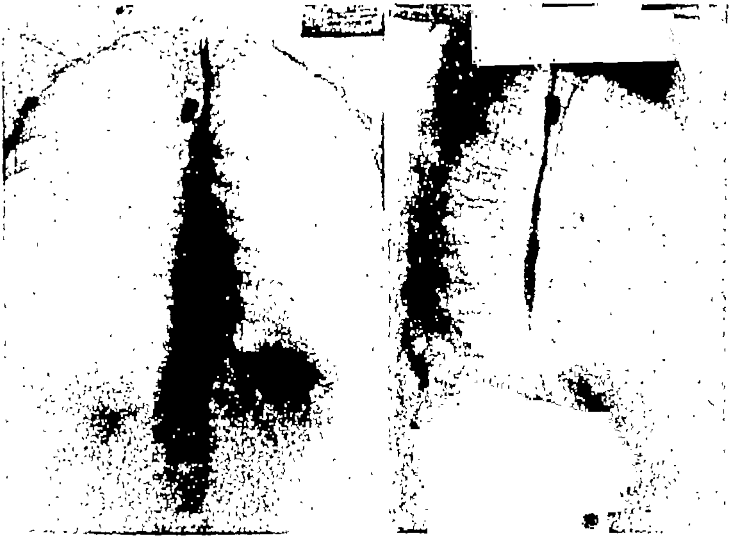
Fig. 1. Fig. 2.

Fig. 1.—Case 1. Anteroposterior roentgenogram with barium meal showing relationship of bullet to esophagus.

Fig. 2.—Case 1. Lateral roentgenogram with barium meal showing relationship of bullet to esophagus.

Missiles may lodge very close to the esophagus and not damage it in some patients. Gatschers[11] has described such a patient, in which the bullet lying adjacent to the thoracic esophagus could be seen to move with the organ on fluoroscopic examination. This patient was discharged to duty after three months' observation. Four of the twenty mediastinal foreign bodies reported by Sommer and McColloch[21] lay adjacent to the esophagus. Their relationship was well demonstrated by barium studies of the organ. It certainly seems wise to remove foreign bodies so located.

CASE 2.—A 35-year-old soldier was struck by a bullet, which perforated the lower left arm and penetrated the left hemithorax Feb. 27, 1945. The arm wounds were debrided the same day, and a plaster encasement applied for the compound fractures of the radius and ulna. A very limited left thoracotomy was performed with debridement of the wound and the fractured seventh rib. Penicillin, 820,000 units was given intramuscularly February 28 to March 3. At various times between March 5 and April 9, 840,000 units were given intramuscularly. Fluid was aspirated from the left pleural cavity March 5 and 12. The patient was admitted to the center March 28. Roentgenogram showed the pistol bullet to lie in the upper mediastinum. Films taken after the ingestion of barium (Figs. 1 and 2) demonstrated that the bullet lay just to the right of the esophagus, which was displaced to the left. May 1 the right pleural cavity was opened with resection of the fourth rib. An excellent exposure of the upper mediastinum was attained. The bullet, which lay under the mediastinal pleura, was readily removed. The convalescence was complicated by subcutaneous emphysema, probably due to positive pressure used in expanding the lung at the conclusion of the operation, and atelectasis. The patient was bronchoscoped May 5. He made a complete recovery and is seen (Fig. 3) twenty days after operation. A postoperative film (Fig. 4) taken nineteen days after operation shows the normal appearing lung fields.

Fig. 3.—Case 1. The patient twenty days after operation.

A personal observation of spontaneous discharge of a shell fragment into the thoracic esophagus without untoward results led to an effort to dis-

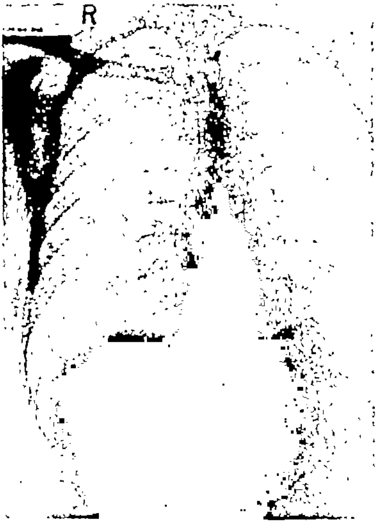

Fig. 1.

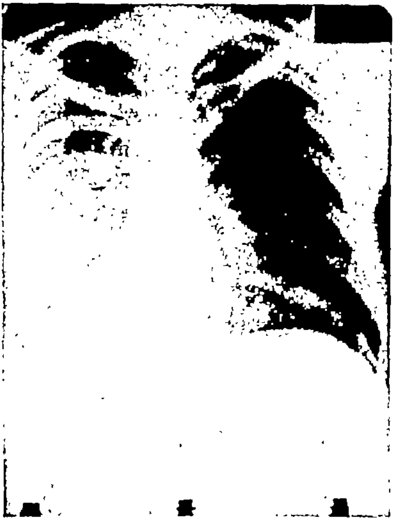

Fig. 5.

Fig. 1.—Case 1. Posteroanterior roentgenogram nineteen days following operation; normal pulmonary fields.

Fig. 5.—Case 2. Anteroposterior roentgenogram; the foreign body obscured by the cardiac shadow is faintly seen.

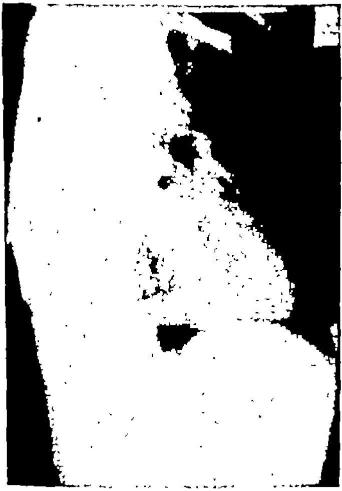

Fig. 6.

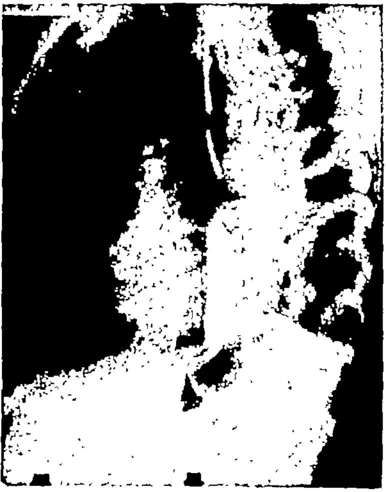

Fig. 7.

Fig. 6.—Case 2. Lateral roentgenogram demonstrating the large metallic missile behind the cardiac shadow.

Fig. 7.—Case 2. Oblique roentgenogram with barium meal; the deep notch at the earlier site of the foreign body is well shown.

cover such cases in the literature. Schilling[20] observed a patient who had sustained a penetrating wound of the neck. The soldier was expectorating blood and suddenly coughed up the bullet. A tracheoesophageal fistula, evidenced by coughing whenever the patient ate or drank, persisted for some days. No operation was performed and the fistula closed spontaneously, a most fortunate event. Turner[22] reported the case of a man, who had sustained a perforating shrapnel wound with the point of entrance at the angle of the jaw. The bullet could not be located at operation, during which a tracheotomy was performed. The patient had difficulty in swallowing but said nothing of it because of fear of a second operation. Two weeks after injury he suddenly gulped and swallowed an object with relief of his distress. The bullet was passed by rectum two days later. Turner[23] later reported another World War I incident. A soldier received five perforating bullet wounds of the chest, a sixth bullet lodged in the lung, and a seventh entered the chest and was passed by rectum; it had apparently perforated into the esophageal lumen. Hetzar[14] detailed a finely illustrated case of late esophageal perforation by a bullet with spontaneous cure. The early roentgenograms demonstrated the 30 caliber bullet lying to the left of the esophagus at the level of the seventh dorsal vertebral body. Later films failed to show the missile. A barium study of the esophagus showed a dilated lumen just above the point of earlier lodgment. The patient had no symptoms fifteen months after injury.

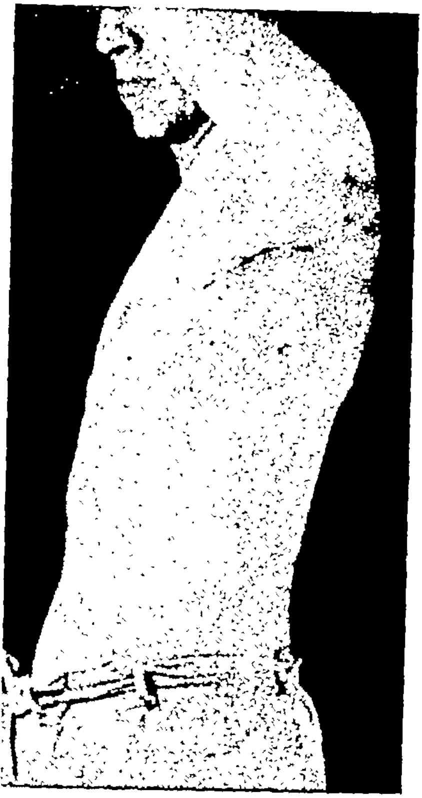

Fig. 8.—Case 2. The patient with the healed wound of entry in the left axillary region.

CASE 3.—A 25-year-old soldier sustained a penetrating shell fragment wound of the left thorax with a compound fracture of the fifth rib Jan. 23, 1945. The sucking wound was promptly debrided and closed. An intercostal drainage tube was inserted. January 23, 100,000 units of penicillin were given intramuscularly, and 240,000 units were given February 11 and 12. The patient was admitted to the center February 25. The accompanying roentgenograms taken February 14 (Figs. 5 and 6) demonstrated a large, rugged, metallic foreign body lying close to the mediastinum in the midthorax. New roentgenograms of February 26 taken prior to a planned operation for removal of the foreign body failed to reveal it. The patient was completely examined by fluoroscopy without the missile being found. A barium study of the esophagus (Fig. 7) then showed a notch at the site of entrance of the foreign body into the lumen. The patient (Fig. 8) had been unaware of the passage of the foreign body. He returned to the United States quite well April 13.

Kay[16] has discussed briefly eight patients with esophageal wounds treated after their return to the United States. In one case an esophagotracheal fistula healed without operation. There were four other cases with associated injuries of the trachea. The patients as a whole suffered with paraesophageal and mediastinal abscesses, fistulas, and strictures. This group of patients shows that the course of esophageal wounds may be long and complicated before cure is attained.

SUMMARY

Esophageal wounds are some of the most serious that occur in war, both from the standpoint of the dangers inherent in themselves and from damage to neighboring large blood vessels and the trachea. There is evidence in the literature, however, that prompt surgical intervention will save the lives of some of these patients. The antibiotic drugs now available and the improved methods of anesthesia and resuscitation have changed the prognosis of esophageal wounds from that of earlier wars. Adequate and prompt drainage of mediastinal and pleural infections should be carried out for patients developing these complications. Surviving patients may have fistulas for some time or develop strictures.

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SPONTANEOUS HEMOPNEUMOTHORAX TREATED BY DECORTICATION

A CASE REPORT

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OTEEN, N. C.

INTRODUCTION

PITT[30] and Rolleston[31] in 1900 independently reported what are considered to be the first cases of idiopathic spontaneous hemopneumothorax. Hopkins[16] in 1937 recorded the first to be reported in a female patient. Hartzell[13] in a review of the literature in 1942 found forty cases and added three of his own. Of all cases reported up to that time fourteen, or 33 per cent, were fatal. Since then several more have been reported,[2, 14, 27, 29, 30, 11b, 41] some of which have been fatal.[14] Autopsies[13, 14] have been performed on a number of patients without conclusive proof concerning etiology. As far as can be determined, this is the first patient who received an operative exploration.

Samson and Burford[34] have a most excellent and interesting review of the history of pulmonary decortication. Fowler,[11a] on Oct. 7, 1893, performed the operation of pulmonary decortication for chronic empyema. Delorme,[6] on Jan. 25, 1894, performed the second such operation. The operation was attempted in subsequent years but finally came into disuse by most surgeons. Gurd[8] of Canada is one contemporary surgeon who continued the procedure to some extent in the treatment of chronic empyema.

During the last war an entirely new concept of the pathology and pathogenesis of hemothorax was formed.[1, 3-5, 18, 19, 21, 22, 32-35, 37, 39, 42, 43] It was the realization of this new approach to the subject which led Burford and associates[32, 33] to perform decortication for the treatment of traumatic hemothoraces in 1943. Since that time, many cases of pulmonary decortication have been performed for traumatic hemothorax[42, 43] and for certain types of empyema.[35, 39] However, we have been unable to find in the literature any instance where this principle of decortication has been applied in a case of idiopathic spontaneous hemopneumothorax.

ETIOLOGY

Even though no definite proof of an anatomical nature can be shown, the most generally accepted explanation of the etiology is that of rupture of an emphysematous bleb and tearing of the pleural adhesions.[2, 13, 14, 16, 17, 23, 29, 44] However, there are as many theories concerning the cause of hemopneumothorax as there are theories for the cause of spontaneous pneumothorax.

PATHOLOGY

For many years there was a misconception concerning the clotting of blood in the pleural cavity. Merlick and Spooner[23] showed that the blood clots in

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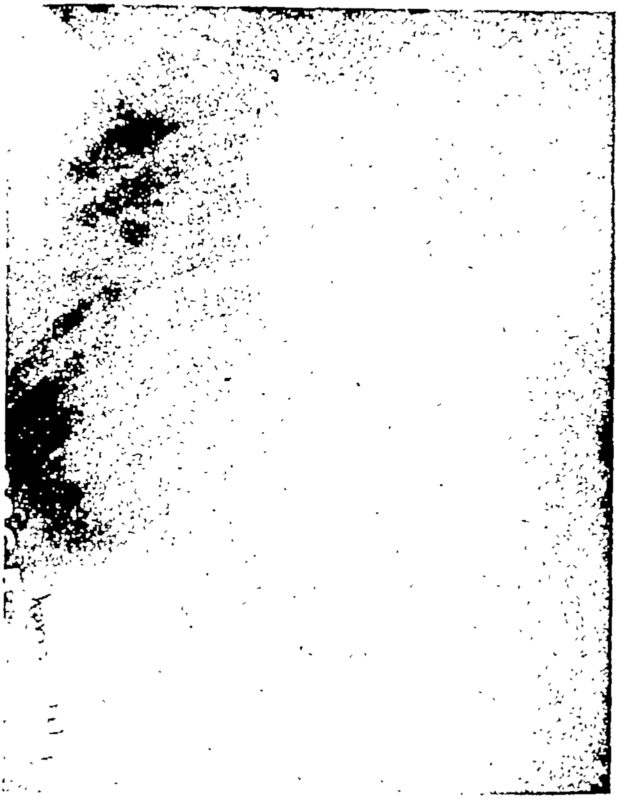

Fig. 1.—Shows appearance of chest immediately after hospitalization and prior to aspiration of chest. This picture was taken with patient in incumbent position.

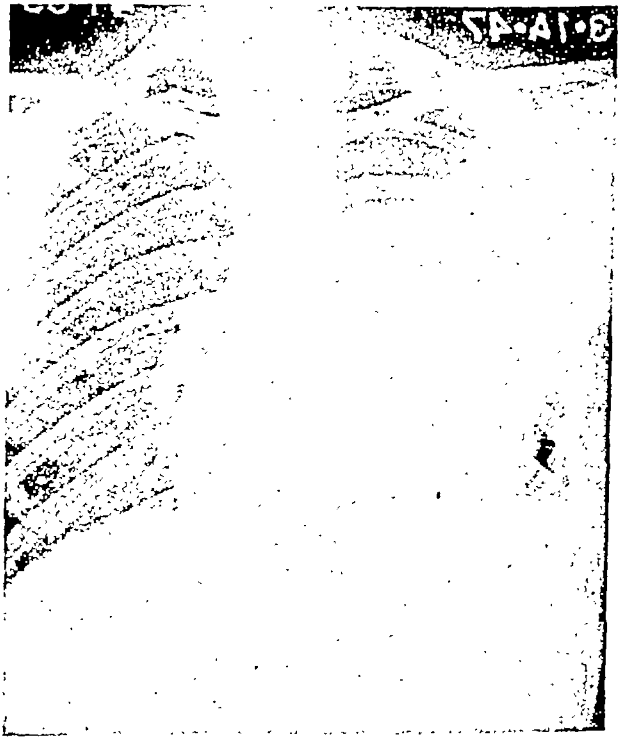

Fig. 2.—Appearance of chest in the P. A. diameter after attempts to aspirate chest preoperatively.

the pleural cavity. The blood clots rapidly as it goes into the pleural cavity, but *the motion of the heart, lungs, and diaphragm causes a defibrination of the blood.* This fibrin is precipitated out, usually on the pleura. What is left is simply serum and cells. This will not clot unless fibrinogen is added. For this reason, we can almost always aspirate a pleural cavity into which there has been bleeding and obtain a red fluid of simply serum and cells. Frequently, after a few days a pleural exudate is thrown out which leads to a "secondary clot." This secondary clot is what has led to much of the misunderstanding concerning clotting of blood in the pleural cavity.[1, 9, 17, 20, 24-27, 29, 30, 45] This phenomenon, however, was fully realized by such men as Trousseau[24] in 1834 and Elliott[10] in 1916.

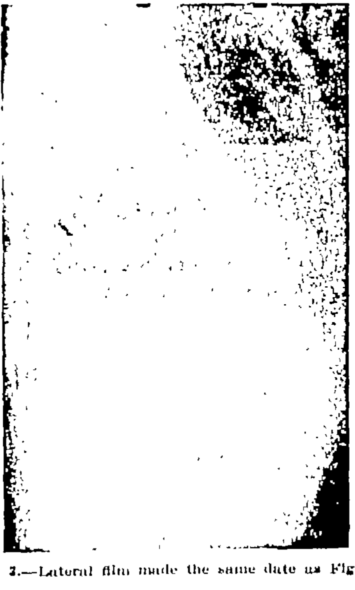

Fig. 3.—Lateral film made the same date as Fig. 2.

If the blood is not immediately aspirated within two to three days following the development of a hemothorax, there is deposited a thin layer of clotted blood and fibrin[8, 21, 22, 32-35, 43] which is continuous over both visceral and parietal pleura. A closed envelope is formed with the inner surface toward the hemothorax (serum and cells) and the outer surface loosely adherent to the pleura.[34] Within seven days following the hemothorax, there is fibroblastic and angioblastic proliferation in this layer. The fibroblastic envelope or membrane then *grows thicker by deposition of successive layers of clotted blood and fibrin.* Within four weeks, adult fibrous tissue is located on the outer surface of this fibroblastic membrane. Within six to seven weeks, small arterioles can be seen to develop in the outer layer. The advancing inner wall remains composed of

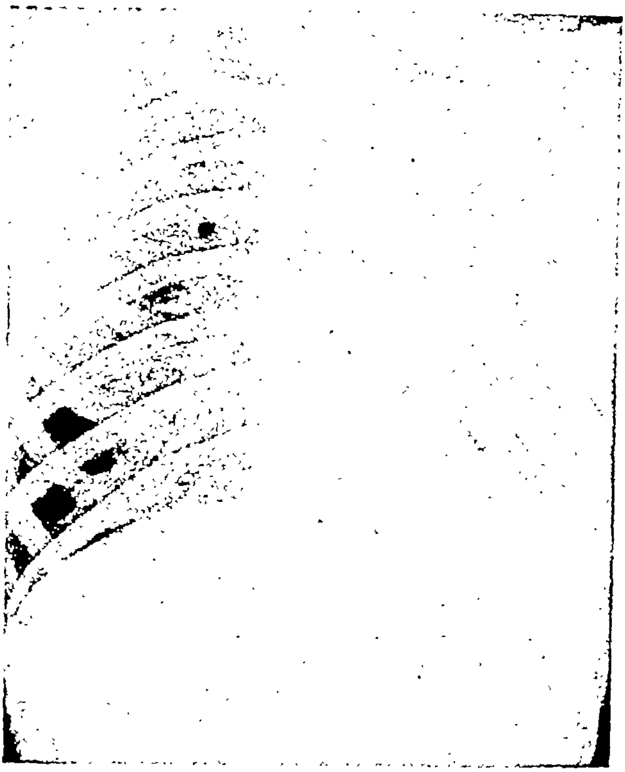

Fig. 4.—Appearance of chest one week after operation. The lung is re-expanded except for a small pneumothorax at the apex which disappeared in two weeks.

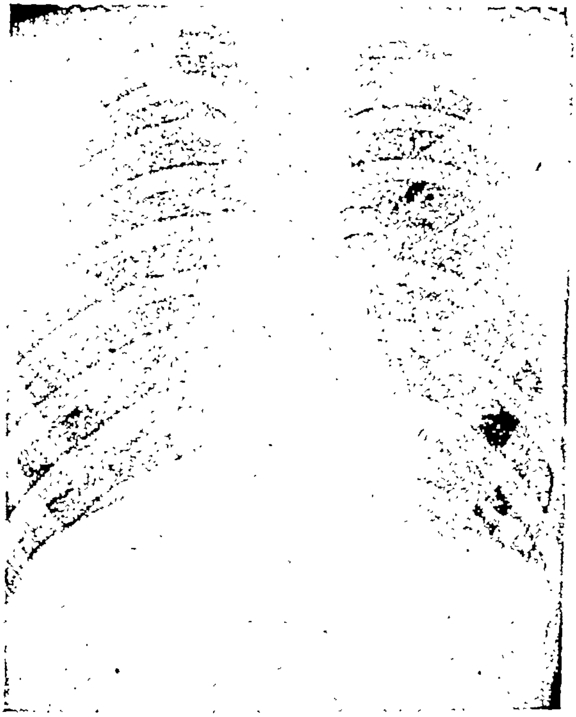

Fig. 5.—Appearance of chest eight months after operation.

young cellular tissue, and even single wandering cells can be seen.[21] Eventually there is almost complete fusion of the outer wall with the pleura. This leads to fibrothorax, empyema, reduced pulmonary function, late pulmonary suppuration, bodily deformity, and frequently pulmonary hypertension.[15, 22, 30] The above applies to massive hemothoraces, and it is recognized that small amounts of blood can, and frequently will be absorbed.[13, 14, 20, 32-34]

TREATMENT

The desired treatment in view of the pathology is early and vigorous aspiration. According to Sellars,[26] there is no need to fear a recurrence of bleeding. In addition to vigorous aspiration, whole blood transfusions, oxygen, rest, and such medical measures as are indicated may be employed. During convalescence, breathing exercises are very helpful. If aspirations are not successful in returning the lung to complete expansion and full function after three to five weeks, a thoracotomy with decortication should be performed.

CASE REPORT

C. M., a 31-year-old white veteran was admitted to this hospital on March 13, 1947. His past history was noncontributory until January, 1946. At this time, because of vague chest pains, he received a complete examination with x-ray of his chest. This revealed no pulmonary pathology. He was well until Feb. 15, 1947, at which time, while driving a car over a very rough road he noticed vague discomfort in the left chest, which lasted from ten to fifteen minutes. Because of this, he stopped the car. He then experienced a sudden sharp, severe pain in his left chest, and fainted. Examination by a private physician revealed a marked shift of his mediastinum to the right. He was told that his chest was "full of fluid." He received symptomatic treatment at home for ten days, and was then sent to a hospital. At this time, he had a septic temperature, severe anemia, and marked dyspnea. X-ray examination (Fig. 1) revealed obliteration of the entire left chest and a marked shift of the mediastinum to the right. Aspiration yielded blood. All cultures and other laboratory findings were normal. Sputa were negative for acid-fast bacilli. He was transferred to Oteen on March 15, 1947. His findings here were the same as those previously noted except that now air was present above the loculated fluid (Figs. 2, 3). The tuberculin skin test was negative. On March 25, 1947, an exploratory thoracotomy was performed. The lung was found collapsed and adherent to the mediastinum. The chest cavity was typical of an organizing hemothorax. After the fibroblastic membrane on the parietal pleura was incised there was found a heterogeneous mass of fibrin, degenerated red cells, necrotic tissue, and serum in loculated pockets filling the whole interior of the fibroblastic envelope which occupied most of the chest cavity. The fibroblastic membrane over the visceral pleura was about 0.5 cm. in thickness. This membrane was removed from the visceral pleura and diaphragm. Each lobe was freed from the other.

No cause of the hemothorax was found. The lung was re-expanded and the chest closed about a Pezzer catheter which was attached to a Stedman pump. Fig. 4 shows the appearance of the chest one week postoperatively. The patient's postoperative course was uneventful and the catheter was removed on the third postoperative day. He was discharged April 25, 1947, one month after operation. At this time his lung had fully re-expanded and his vital capacity had increased from 1,900 preoperatively to 4,000 postoperatively. Fig. 5, an x-ray film made Dec. 5, 1947, shows appearance of the chest eight months after operation.

SUMMARY

The history of spontaneous hemopneumothorax and decortication is briefly reviewed. The pathology, etiology, and treatment of hemothorax are discussed and a case of idiopathic spontaneous hemothorax reported. As far as the authors could determine, this is the first such case which was explored operatively and a decortication performed.

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HEMANGIOMA OF THE LUNG

A Review of Four Cases, Including Two Not Previously Reported, One of Which Was Complicated by Brain Abscess Due to H. Influenzae

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FROM the scarcity of reports in the literature, hemangioma of the lung appears to be an uncommon lesion; while from the increasing frequency of such reports in recent years, it is evident that with a higher index of suspicion its clinical recognition is becoming more frequent. In 1941 Dauphinee and Hepburn[8] reported for the first time the successful treatment by pneumonectomy of a patient whose condition was correctly diagnosed clinically. They reviewed the literature to that date, and mentioned the cases of Bowers,[3] of Rodes,[14] and of Smith and Horton,[15] all of which presented features similar to their own case. They also reviewed the reports of four other angiomatous lesions of the lung, which were probably not similar to those under discussion. Since then, nine additional cases have been recorded in the English literature, bringing the total of traced reports of the lesion to thirteen.[1, 2, 5, 6, 9, 10, 11, 17] It is proposed to review two of these cases,[8, 9] to report briefly one more, and to report in detail a fourth case which was complicated by a brain abscess. All four were observed in Toronto.

Case 1.—Mrs. J. S.[8] On Feb. 14, 1940, this woman of 23 years underwent right pneumonectomy by Drs. N. S. Shenstone and R. M. Janes, who found a large cavernous hemangioma in the midportion of the lower lobe. It measured 8 by 6 by 4 cm., and consisted of many intercommunicating cavernous sinuses, varying in size up to 1.5 cm. in diameter. By injection it was shown to communicate with a branch of the pulmonary artery.

The patient had never been robust. Clubbing of the fingers was first noticed at the age of 15 years, and at this time she became aware of shortness of breath on mild exertion. When 21 years of age, she was re-examined because of chest symptoms. Cyanosis was now present, and a radiograph of the chest showed an infiltrating process of the right middle and lower lobes, which by lipoidal injection was shown not to be bronchiectatic. The hemoglobin was 95 per cent (14.8 Gm. per cent), and the red blood count 4.7 million per cubic millimeter. Over the next year and a half she became more dyspneic, more cyanosed, and more easily tired. Following an attack of dizziness, faintness, and thick speech, re-examination showed marked cyanosis and clubbing of the fingers. There was no evidence of congenital heart disease, and chest radiograph confirmed the presence unchanged of the shadows previously noted in the right lower lung. Hemoglobin was now 140 to 146 per cent (21.8 to 22.8 Gm. per cent), and the red blood count 9.0 to 9.6 million. Arterial blood oxygen saturation was 72 per cent (normal 95 per cent). The total blood volume was increased. Following pneumonectomy, the cyanosis disappeared promptly. Two months later, the hemoglobin was 71 per cent, and the red blood count 4.3 million. A long standing acnelike eruption of the face had vanished, and her general health was improved both subjectively and objectively. Fourteen months after operation the clubbing of her fingers had disappeared completely. She has since had two children and is well.

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Case 2.—Mr. R. B.[9] At operation by Dr. R. M. Janes on Oct. 4, 1941, this man of 30 years had two hemangiomas removed by local dissection from the right lower lobe of his lung. They measured respectively 5 by 4 by 3 cm. and 3 by 4 by 2 cm., and consisted of dilated and prominent vascular channels, whose walls showed irregular thickening, and were considered venous rather than arterial in type. At a second operation on June 25, 1942, two more hemangiomas were removed from the left lower lobe. They measured 7 by 2 by 1 cm. and 1.5 by 0.8 by 0.4 cm. respectively, and consisted of well-defined blood spaces with marked cavernous dilatations lying just beneath the pleura.

The patient had been well until 1940, when, following strenuous effort during military training, he suffered two severe hemoptyses. Radiographs of the chest were negative, and repeated sputum examinations failed to show tubercle bacilli. He was discharged from the army, and remained well for one year save for some asthmatic attacks of indeterminate origin, attributed initially to his occupation. Following three further hemoptyses, he was referred for investigation.

He was rather thin and pale, and his lips and fingernails were cyanotic. There were multiple small hemangiomas of the lower lip, which he stated had been present for a long time. A soft blowing murmur was later heard in the region of the right cardiophrenic angle, the chest being otherwise clear on physical examination. There was no fever, cough, or sputum. Tuberculin test was negative. hemoglobin was 67 per cent. The red blood cells were microcytic and hypochromic, a picture compatible with his recent hemoptyses. Radiographs of the chest showed two shadows in the lower right lung, and one or possibly two in the lower left lung field. Following his first operation he felt well, his cyanosis lessened, and he was capable of more exertion than formerly. The second procedure further increased his exercise tolerance. He was able to return a little later to his former occupation without recurrence of the asthmatic attacks. There has been no further hemoptysis.

Case 3.—Mr. J. N. McA. Although a circumscribed shadow was present in his chest radiograph, this subjectively well young man was accepted in 1943 for unrestricted service in the Royal Canadian Air Force. On discharge in 1945, when 21 years of age, the shadow was present unchanged. It was round, about 5 cm. in diameter, and lay immediately above the right diaphragm, extending into the posterior diaphragmatic sulcus. Physical and other examination was completely negative. His red blood cells numbered 5.1 million, and his hemoglobin was 107 per cent.

Operation was advised, and on Aug. 13, 1945, Dr. N. S. Shenstone found a slightly pulsating tumor in the right lower lobe. A right lower lobectomy was performed, with uneventful postoperative recovery.

The specimen revealed a large endothelial-lined cavity lying close beneath the pleura of the lower lobe of lung. It measured 5 by 5 by 1 cm. and was enclosed by a thin wall of varying thickness (Fig. 1). Several thin-walled vessels lay immediately adjacent to it. At least one of these entered the main cavity, which contained fresh blood clot.

Case 4.—A. H., a boy of 13 years, was definitely cyanotic when 5 years of age, and may have been a "blue baby" at birth. He had suffered since then from persistent clubbing of his fingers and toes, peripheral cyanosis, and a decreased exercise tolerance. He was rather underdeveloped, and although latterly able to walk two to three miles in comfort, never, due to dyspnea, had he been able to run or keep up with his fellows at games. For four years before death he had experienced recurrent temporal headaches. These appeared during the daytime about once weekly, and were somewhat relieved by aspirin. They would last most of the day, and were occasionally associated with vomiting.

On Aug. 13, 1940, he underwent tonsillectomy. The operation and postoperative period were uneventful, he gained a few pounds and felt well until October 23, two and one-half months later. On arising that morning, he felt weak, momentarily "went black," and fell. Recovering, he continued to school, where during the day he suffered an episode of blurred vision, weakness of the left hand, and clenching of the jaw. A similar attack of shorter duration occurred the next morning. That evening there was a true Jacksonian attack, with continued twitching of the left eye and hand over one and one-half hours. Following this, he lost consciousness for one half hour. He was referred to hospital, where during the next few days several similar attacks occurred. These were associated with increasing temporal headache, drowsiness, and weakness of the left arm. He was nauseated, and vomited several times.

On October 29, his seventh day of symptoms, he was admitted to the Neurosurgical service of the Toronto General Hospital. On admission he was conscious, and bright mentally. He was poorly developed. Oral temperature was 99° F. and respirations 20 per minute. There was cyanosis of the lips, ears, and tongue, and marked cyanosis and clubbing of the fingers and toes. His chest was clear on physical examination. The heart was enlarged slightly and beating regularly at 80 per minute. No murmurs were heard. There was marked weakness of the left face and the distal muscles of the left arm. There was slight weakness of the left leg. Plantar responses were downward. Sensation was not disturbed. There was no papilledema. He was not dehydrated. Laboratory studies revealed a normal urine. Blood examination showed a red cell count of 6.4 million. The hemoglobin was 117 per cent by the Sahli method. White cells numbered 9.8 thousand. Immersion of the hands in hot water did not alter the cyanosis of the finger tips. This was felt to favor its central rather than peripheral origin.

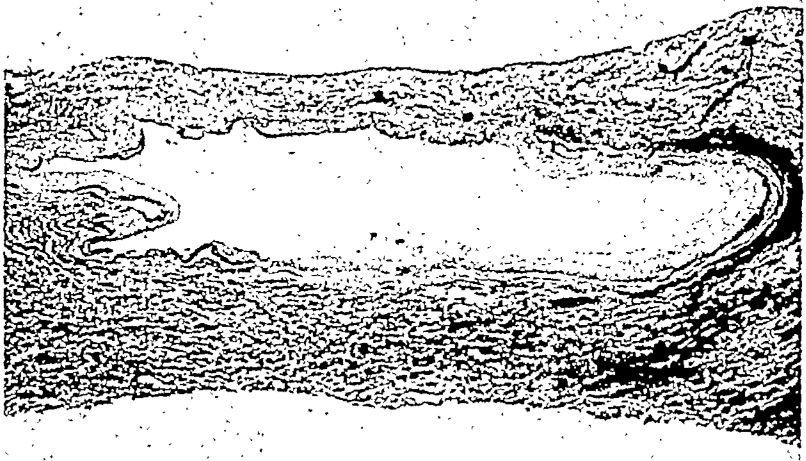

Fig. 1.—Case 3. The hemangioma is shown in cross section, lying close beneath the pleura. Its light colored wall varies markedly in thickness, and is surrounded by a darker zone of atelectatic and organized lung. Several small vessels lie between the atelectatic lung and the vascular wall. These are best seen immediately adjacent to the latter's upper and left-hand limits. (Photograph ×2½.)

Roentgen study of the chest showed a slightly enlarged heart of normal configuration. There were mottled densities through the lower two-thirds of the right lung field, except in the region of the costophrenic angle. These were most marked in the hilar region of the lower lobe area (Fig. 2). The tuberculin test was negative. An orthodiagram showed the cardiothoracic ratio to be 52 per cent. Cerebrospinal fluid contained 70.2 mg. of protein per cent. No cells were seen. It was faintly xanthochromic.

In the presence of cyanosis and clubbing of the fingers and toes since early childhood, an initial tentative diagnosis of congenital heart disease was entertained. The cerebral lesion was considered to be either cerebral softening secondary to vascular occlusion, or a brain abscess, either possibly the result of bacterial endocarditis superimposed on a congenital defect of the heart. Daily blood cultures were taken, from which no growth was obtained. During the next week his headache recurred, and the weakness of the left arm and leg increased. Papilledema appeared and became progressively more marked. Brain abscess was now considered the most likely cranial lesion, and accordingly a craniotomy was performed on November 8, the eleventh hospital day. A large, egg-shaped, encapsulated abscess, measuring 6 cm. in its long axis, was found in the right Rolandic area. It was ruptured during removal. Preoperatively the patient had been started on penicillin, 30,000 units intramuscularly every three hours. A further 25,000 units were instilled into the operative site following removal of the abscess. A culture of the abscess contents was sterile.

After a few days of favorable progress, the boy's headache and papilledema again began to increase. Aspiration of the operative site showed that the abscess had recurred, and from the pus obtained a pure culture of *Hemophilus influenzae* was grown. Subsequently, he underwent repeated aspiration and surgical drainage of locally recurring cerebral abscesses. The organism was streptomycin sensitive, and consequently streptomycin 1,000,000 units daily was given intramuscularly for a period of ten days. No coincident improvement was noted, and as the drug was in short supply it was discontinued. Enlargement of the craniotomy was followed by the growth of a large brain fungus. This was excised six weeks before death, only to recur. Terminally a meningitis developed.

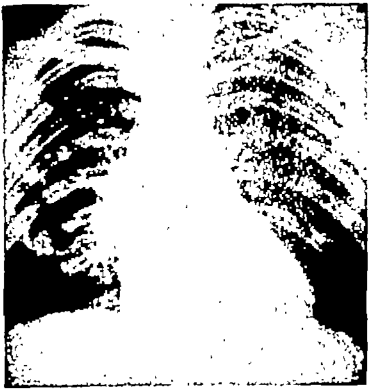

Fig. 2.—Case 4. Note the infiltration of the lower half of the right chest, most marked in the hilar region of the lower lobe.

A pure culture of *H. influenzae* from the abscess was obtained on a second occasion six weeks after its initial isolation.

Repeat radiographs of the chest on Jan. 17 and Feb. 5, 1947, showed no change in the previously described shadows in the right lower lung field. In the presence of the brain abscess, these were considered probably inflammatory in nature, and were felt to be compatible with the changes of bronchiectasis. However, in the absence of cardiac murmurs, and of a diagnosis of a definite type of congenital heart lesion, an arteriovenous aneurysm of the lung was suggested as a possible explanation of the lung shadows, the polycythemia, the cyanosis and the clubbing of the fingers and toes. The boy's general condition at this time prevented more complete investigation.

At autopsy, the subject weighed 55 lb. and measured 4 feet, 6 inches in length. There was marked clubbing of the fingers and toes. Through the center of a large right-sided parietal craniotomy a soft fungus of the brain extended 4 cm. beyond the surrounding scalp. On removing the brain, a heavy plastic basilar meningitis of faintly greenish-yellow pus was seen to extend out the lateral sulci to fade into a much less marked meningitis over the cerebrum. Similarly, a moderate spinal meningitis was present. The body of the right ventricle was distorted, and pulled well out into the herniated brain substance where it became continuous with a small ragged cavity in the periphery of the fungus. Apart from a mild ependymitis, and the distortion of the right lateral ventricle, the ventricular cavities were not dilated or otherwise remarkable. There was no inflammation of the middle ears, the mastoid cells, or the accessory nasal sinuses.

The heart showed moderate generalized hypertrophy. Both ventricles were slightly dilated. It weighed 180 Gm. as compared to the normal average weight of 124 Gm. for a boy of 12 years.[4] The left ventricular wall measured 1.3 cm. and the right ventricular wall 3 mm. in thickness. The valves and valve orifices were normal. There was no functional congenital defect, although a probe could be passed obliquely through a minute opening in the basal portion of the interventricular septum. The foramen ovale was closed, and the ductus arteriosus obliterated.

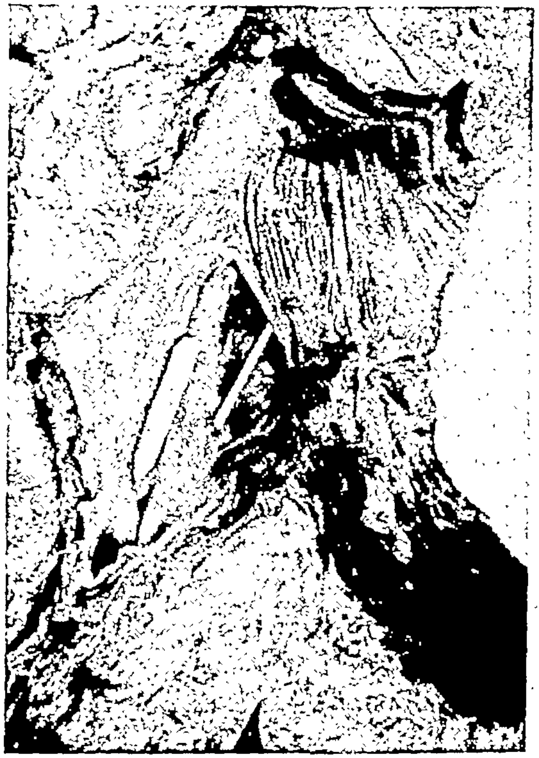

Fig. 3.—Case 4. Note the satellite loculations in the lower right corner, lying peripherally about the main cavity of the hemangioma. The markers lie in communicating blood vessels.

The lungs were of normal size, grayish pink, and crepitant throughout. On dissection a large endothelial-lined blood-containing cavity was found lying closely beneath the pleura of the hilar aspect of the right lower lobe (Fig. 3). This presented a main cavity measuring 4.5 by 2.5 cm., from the lower corners of which there were two large extensions. A lesser blind pouch extended upward, while on its lateral wall there was another irregular sacculation. When filled with blood, the whole may have measured less than 1 cm. in thickness, the flat axis lying parallel to the pleural surface with which in places its outer wall was in contact. Around the periphery of the main cavity there were several small satellite loculations measuring 3 to 6 mm. in diameter. These communicated irregularly among themselves, and with the main cavity. Two communications were noted between the main cavity and the vascular tree, one through a thin-walled vessel 3 mm. in diameter, and one through a rather thicker-walled vessel 5 mm. in diameter. Other communications may have been destroyed in the initial rough dissection. No intrapulmonary source of infection was demonstrated.

Microscopic sections through the periphery of the main cavity showed the multiloculated structure, and extreme variation in thickness of the cavern walls (Fig. 4). Some generalized increase and heaviness of the vascular tree was demonstrated in the other lobes, this being most marked in the right lung, although also present to a lesser degree in the left. The vessel walls were prominent and irregularly thickened. The adjacent lung parenchyma showed in many places a patchy atelectasis and fibrosis.

Microscopic examination of the wall of the abscess removed at operation on November 8 showed a well-defined fibrous capsule. Although no definite age could be assigned, it was considered to have been at least six to eight weeks old.

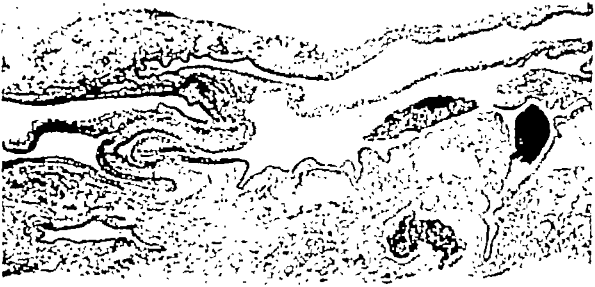

Fig. 4.—Case 4. This section was cut from the periphery of the main cavity of the hemangioma. It shows the multiloculated vascular spaces lying close beneath the pleura. The walls of the vascular spaces vary markedly in thickness. (Photograph ×8.)

DISCUSSION

Hemangiomas of the lung appear to be local manifestations of a generalized congenital tendency to maldevelopment of the blood vessels. As in Janes's case,[9] they may be multiple, and associated as in three other reported cases with hemangiomas of the lips. Similarly in Case 4, the abnormal vasculature seen in the other lobes of the lung again supports a more generalized structural abnormality than was at first apparent. A familial tendency is suggested by Goldman's report[6] of hemangiomas occurring in each of two brothers. The lesions may consist of multiloculated vascular structures, or may present one large central dilatation with or without surrounding satellite loculations, with varying degrees of communication with the main pulmonary vessels. The presence or absence of symptoms largely depends on the extent of these communications, and on the volume of blood passing through them.

A few patients, as in Case 3, may escape any untoward effects of the lesion. In them, diagnosis will result only from the incidental finding of an abnormal lung shadow on chest radiography performed for other reasons. However, it would appear from Case 1, and from the case reported by Makler and Zion,[11] that both the symptoms and the radiographic findings may progress. It would seem probable that eventually all or at least most patients will develop symptoms.

Blood passing from the pulmonary artery through the lesion to the pulmonary veins will return unoxygenated to the left heart. Depending on the extent of the communication with the pulmonary vessels, and on the volume of blood flow, this will lower to a varying degree the oxygen saturation in the systemic circulation. If this lowered oxygen saturation is marked, dyspnea and cyanosis may result, with secondary clubbing of the fingers and compensatory polycythemia. The polycythemia in turn may bring its accompanying complications. The patients reported by Dauphinee and Hepburn,[8] and by Smith and Horton,[15] both consulted their physicians following episodes of dizziness, faintness and thick speech, possibly the manifestation of thrombosis in cerebral vessels.

Again, as in Case 2, hemoptysis may be the presenting feature. This may be of extreme degree, as in the fatalities reported by Bowers[3] and Rodes.[14]

Prior to operation, Case 1 had suffered for years from intractable acne of the face. Two months after operation and the correction of her cyanosis, the eruption had completely disappeared, suggesting that the previous relative anoxia may have been a factor in lowering the resistance of her skin to infection. Possibly a similar factor of lowered oxygen saturation may have favored the development of the brain abscess in Case 4, and of brain abscesses in other cases of cyanotic cardiorespiratory diseases. Robbins[13] reported three cases of brain abscess associated with the tetralogy of Fallot occurring among fifty-three cases of congenital heart disease encountered among 7,880 autopsies at the Mallory Institute. Although small, this series would suggest that brain abscess occurs more frequently than usual in cases of cyanotic heart disease. Of a total of twenty-four reported cases of brain abscess occurring in cases of congenital heart disease, thirteen were associated with the tetralogy of Fallot, a condition resembling Case 4 both in the presence of cyanosis, and of an arteriovenous shunt which may sidetrack the pulmonary capillary circulation.

It has been suggested that infection of the brain in congenital heart disease may occur either by growth of bacteria from the blood stream in an area of encephalomalacia secondary to cerebral vascular occlusion, or by infective brain embolism.[16] In Case 4, and in the majority of the thirteen tetralogies of Fallot, no primary source for such an infected embolus was demonstrated. Nor was there, in Case 4, any particular episode suggestive of cerebral vascular occlusion prior to the onset of symptoms directly attributable to the abscess. It is interesting that in two of these thirteen cases, as in Case 4, the infecting organism was *H. influenzae*,[7] an unusual cause of brain abscess. It has not been seen previously in the Department of Pathology at the Banting Institute, and apart from the above, only one other case was noted in the recent literature.[12] As a cause of meningitis it is common in infants and not uncommon in children.[18] It can occur in the normal respiratory tract. It has been isolated in cases of sinusitis, and of various infections of the lungs. In the latter, it has been grown from the blood of living patients. A specific tonsillitis has been ascribed to it. Culturally, it is an obligatory anaerobe which grows best in an atmosphere 10 per cent of which has been replaced by carbon dioxide. Hemoglobin or one of its compounds is almost essential in the media for its laboratory growth.[18]

From the age of the abscess as determined by the structure of the abscess wall removed at the initial operation, the cerebral infection occurred at least six or eight weeks prior to the onset of symptoms. In the absence of any other focus, it seems likely that the primary infection was in the throat. Infection of the brain could have followed the tonsillectomy on Aug. 13, 1946, either by the passage of an infected embolus from the site of operation through the arteriovenous shunt in the lung, or from a transient bacteriemia occurring during the operation. In the latter case, growth in the brain may have been permitted by lowered tissue resistance secondary to relative tissue anoxia. More likely, it occurred in a minute and clinically unrecognized area of encephalomalacia, the result of thrombosis secondary to the polycythemia. Such a site would reproduce to a great extent the optimum laboratory conditions for the culture of *H. influenzae*.

It is evident that hemangiomas may in effect function as arteriovenous shunts of the lung, and in this capacity produce symptoms varying in degree from negligible to disabling. Its complications, in the form of hemoptysis and cerebral lesions, may prove fatal. As the lesion and its effects are usually amenable to complete cure by surgery, its correct diagnosis assumes particular importance. Diagnosis will depend primarily on the consideration of such a lesion by the clinician as a possible explanation of a patient's presenting symptoms. It should be considered in the differential diagnosis of all unexplained cases of cyanosis, clubbing of the fingers and polycythemia; in all cases of unexplained hemoptysis; and in all cases of indeterminate radiographic lung shadows.

SUMMARY

Four cases of hemangioma of the lungs are reported, one of which was complicated by a brain abscess due to *H. influenzae*. The pathology, symptoms, and complications of hemangioma of the lung are discussed briefly, as is the possible relationship of the pulmonary and cerebral lesions of the last case.

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THE USE OF OXIDIZED CELLULOSE IN PLEURAL SYMPHYSIS

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ST. JOSEPH, MO.

OXIDIZED cellulose was first prepared by Yackel and Kenyon[1] in 1942. Its use as a hemostatic agent in surgery has been reported by Frantz[2,3] and others.[4-7]

During the past few months we have investigated the possibilities of using oxidized cellulose as a mild irritant inserted in the extrapleural space to produce local pleural symphysis preliminary to catheter drainage of large tuberculous tension cavities after the method of Monaldi,[8] or open drainage through a skin-lined fistula as described by Eloesser.[9] The use of an extrapleural irritant is not new. Sarfert[10] as early as 1901 used an extrapleural gauze pack preliminary to draining a pulmonary cavity. In 1919, Bevan[11] suggested the use of gauze soaked in iodine or iodoform gauze placed extrapleurally to secure symphysis of the pleura prior to drainage of lung abscesses. The extrapleural use of cotton gauze with or without the addition of another irritating substance to produce adherence between parietal and visceral pleura prior to drainage of a pulmonary cavity is a standard procedure. We chose an absorbable gauze because it would allow the irritant to be left in place for any length of time. Furthermore, Monaldi drainage could be instituted by insertion of a catheter through a trocar cannula without the added procedure of incising the skin and muscle in order to remove a nonabsorbable pack.

To date, oxidized cellulose has been employed in twelve cases. All of these patients had far-advanced, bilateral tuberculosis with large tension cavities, usually on one side. In each instance the absence of pleural symphysis was demonstrated preoperatively by needling the pleural space nearest the cavity and obtaining the normal intrapleural pressure readings on a water manometer and, in addition, by the injection of Lipiodol into the pleural cavity in three of the cases. In several instances previous fruitless attempts had been made to secure pleural symphysis by the intrapleural injection of small amounts of the patient's own blood.

The point at which the cavity lay nearest to the surface of the chest was determined by x-ray in various positions and with metal markers. This point was usually in the axilla on the involved side at the level of the second interspace. In one case an anterior and in another instance a posterior approach was used. General inhalation anesthesia was employed in all except one case, which was done under local procaine infiltration. The endothoracic fascia was

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approached through the intercostal muscles and the fascia stripped from the inner surface of the adjacent ribs and intercostal muscle over an area approximately 8 cm. square. One or two Oxycel* gauze sponges were placed in the space so created. The muscle, subcutaneous tissue, and skin were closed in layers over this pack. At periods ranging from ten to thirty-nine days after the first operation, pleural fusion was ascertained by failure to demonstrate free pleural space at the operative site on repeated attempts at needle aspiration. In all but one case, to be discussed below, satisfactory pleural symphysis had occurred. Subsequent to demonstration of pleural fusion in cases where Monaldi drainage was planned, the cavity was located by aspirating with the needle attached to a water manometer. When the cavity was found, a catheter was inserted through a trocar cannula. In most instances, the cavity was located with little difficulty. In no case was there any evidence postoperatively of pleural space contamination.

In one case where a cavernostomy through a skin-lined fistula had been planned, the site of the Oxycel pack was opened after ten days and the underlying pleura incised. Although fusion of the two pleural layers had occurred, the area of symphysis was not in the optimum location to insure adequate drainage of the underlying cavity. A second Oxycel pack was inserted and three weeks later the pulmonary cavity was opened through satisfactorily fused pleural layers.

Minor complications occurred in two patients with severe, spreading pulmonary tuberculosis. In one, the wound edges separated on the seventh postoperative day and a hematoma was evacuated after which healing by secondary intention occurred. In the other patient, the wound became painful and indurated but did not break down, and by the twelfth postoperative day signs of inflammation had disappeared. In each instance, thirty days after the insertion of the Oxycel pack, catheter drainage of the underlying cavity was successfully accomplished through the site of the original operation.

In the case in which the drainage was established through a skin-lined fistula, the inflammatory reaction in the area previously occupied by the absorbable gauze could be noted at first hand. At the end of ten days no remains of the gauze were seen, but a moderate amount of serous fluid was present in the space previously occupied by the Oxycel and there was marked inflammatory reaction in the subcutaneous tissue and surrounding muscle. The underlying parietal pleura was thickened and opaque. Microscopic examination of a section of this thickened pleura showed dense fibrous tissue moderately heavily infiltrated with round cells.

SUMMARY AND CONCLUSION

A method of producing localized pleural symphysis prior to transpleural drainage of tuberculous pulmonary cavities is presented. Results in a limited series of cases following the use of an extrapleural pack of absorbable gauze seem to indicate that satisfactory symphysis occurs.

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*Oxycel = Trade name of oxidized cellulose prepared by Parke, Davis & Company, Detroit, Mich.

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Original Communications

THE DIAGNOSIS AND OPERABILITY OF BRONCHIOGENIC CARCINOMA

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Carcinoma of the stomach was responsible for more deaths during the year 1944 in the United States than carcinoma of any other organ.[13] Carcinoma of the respiratory system was exceeded only by carcinoma of the stomach, of the uterus, and of the breast as a cause of death.

The history of the surgical therapy of carcinoma of the stomach is more than twice as long as that of carcinoma of the lung. The five-year survival rate following operation is, nevertheless, very similar in the two conditions. For the stomach it has been reported as 19 per cent by Lawrence,[7] 27 per cent by Custer,[3] and 24 per cent by Walters.[14] For the lung, Ochsner and DeBakey[9] report 22 per cent five-year survivals and Rienhoff[11] 23 per cent. These figures still leave room for improvement. Such improvement will probably be accomplished by more prompt and certain diagnosis, by the exploration of some cases formerly considered inoperable, by a more radical operation, and by a reduction in the postoperative mortality. These aspects will be discussed in the light of experience gained from a study of fifty-six consecutive cases of primary bronchiogenic carcinoma, seen at the Jefferson Hospital during the past fourteen months (April, 1946, to May, 1947, inclusive).

DIAGNOSIS

Earlier diagnosis, and, consequently, earlier treatment, should improve the results of therapy of malignant disease. Early diagnosis is dependent upon

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From the Jefferson Medical College Hospital of Philadelphia.

Read at the Twenty-Seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

Because of an error this paper was omitted from the group of papers presented at the symposium on cancer of the lung which were printed in the preceding issue of the Journal. Some of the discussion, therefore, which concerns this paper will be found in the June issue of the Journal.

—Editor

education of the public in the recognition of premonitory symptoms and upon the education of the general practitioner who first sees the patient. Thus an analysis of the symptoms presented by groups of patients with cancer of the lung is of value. There were fifty male and six female patients in our series. The youngest patient was 41 and the oldest was 75 years old. Twelve patients were in the fifth decade of life, eighteen in the sixth, twenty-one in the seventh decade, and five patients were over 70 years old. The symptoms first complained of are illustrated in Fig. 1. Cough was the most frequent first symptom. This was also true in Lindskog's series.[8] Often, however, the initial symptoms are due to occlusion of a bronchus by the tumor, with infection distal to the point of obstruction. The symptoms persist and the family doctor frequently makes a diagnosis of virus pneumonia. A diagnosis of virus pneumonia, or unresolved pneumonia, in males between the ages of 40 and 70 years should not be made without carefully excluding the possibility that a carcinoma of the lung may be responsible for the symptoms. The third most common initial symptom in our series was pain in the chest. This is often no more than mild discomfort but it is surprising how frequently a patient is able to localize the site of the primary lesion by a deep-seated pain in the chest.

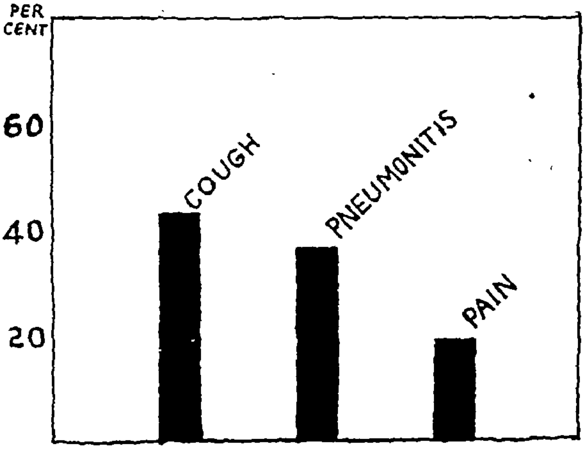

Fig. 1.—Graph of first symptoms.

Fig. 2 is a graph of the frequency of all symptoms complained of. This frequency is very similar to those reported in larger series of cases.[9, 11] The cough was usually unproductive at first. By the time the diagnosis was established, 80 per cent of the patients were bringing up some sputum. The amount expectorated, however, was usually very small. More than one-half the patients had hemoptysis. Weight loss and dyspnea were of equal frequency, and occurred in one-half of our patients. Rienhoff observed weight loss in 40 per cent of his patients, while Ochsner and DeBakey noted a significant loss of weight in 80 per cent of their patients. It is a symptom which is present in pulmonary carcinoma more often than is generally realized. Unilateral wheeze is of considerable diagnostic significance because it is almost invariably the result of a lesion producing some degree of bronchial obstruction. Two of our patients were studied and treated for many months for bronchial asthma. Both these patients exhibited a unilateral wheeze which should have made the attending physician suspicious of a localized bronchial lesion.

X-ray of the chest showed some abnormality in all of Reinhoff's 327 cases. In Ochsner and DeBakey's series a diagnosis of carcinoma was made in 81 per cent of their patients on the basis of the x-ray findings, and in every case there was some alteration of the normal roentgenographic appearance. However, there may be an occasional patient in which x-ray examination of the chest is completely negative. *We had the opportunity to observe one such patient. This man, 55 years of age, was referred to one of us (L. H. C.) because of a persistent* cough. X-ray of the chest was negative (Fig. 3.) He was bronchoscoped, and a growth was found extending into the left main bronchus. A biopsy was performed and squamous cell carcinoma found. As there were no physical signs or x-ray changes, we were completely dependent upon the bronchoscopic findings to determine which side of the chest to explore. The left side of the chest was opened. Nothing abnormal was noted in the lung except a slight thickening of the structures in the hilum. A left pneumonectomy was performed almost entirely upon the basis of the bronchoscopic report. On section of the lung a bronchogenic carcinoma was revealed which did not quite produce bronchial occlusion (Fig. 4). If the patient had not been operated upon, changes in the x-ray appearance of the lungs would have certainly occurred soon, as a result of bronchial obstruction.

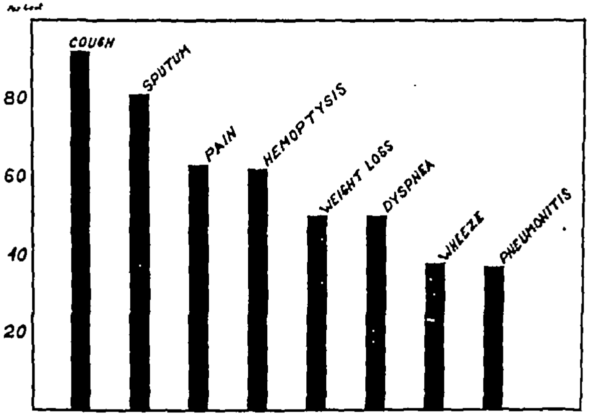

Fig. 2.—Graph of frequency of symptoms.

The only way of making a positive diagnosis of bronchiogenic carcinoma prior to operation is by microscopic examination of a piece of the tumor. A portion of the tumor can be obtained by aspiration through a needle inserted through the chest wall into those growths which are peripherally located. There have been two reported instances in which the tumor has been implanted into the chest wall at the site of the needle puncture.[9] This method of biopsy was not employed in any of our cases. The only other method of obtaining a portion of the tumor for microscopic study is by bronchoscope. All of our cases have

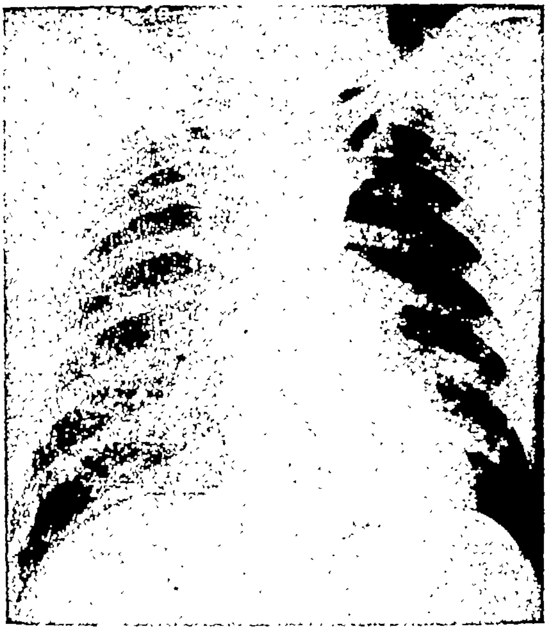

Fig. 3.—X-ray of the chest immediately preceding pneumonectomy in Case 9. No evidence of lesion in left lung.

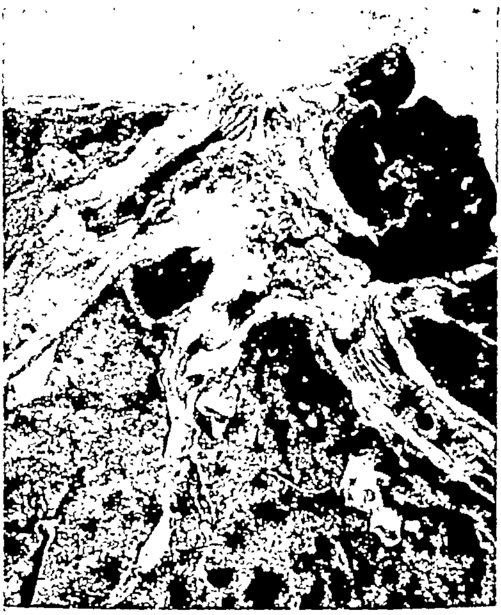

Fig. 4.—Cross-section of left lung in Case 9. Carcinoma can be seen extending into both uppe and lower lobe bronchi.

been bronchoscoped routinely. If the tumor cannot be seen, other suggestive evidence of neoplasm may be observed, such as narrowing, distortion, or fixation of the trachea or bronchus.

In 1946 two of us (P. A. H. and L. H. C.) described a method of diagnosing bronchiogenic carcinoma by the cytologic study of bronchoscopically removed secretions.[2, 4, 5] This method is believed to be superior to the cytologic examination of sputum. It is particularly useful where the tumor is located in the upper lobe or in the periphery of the lung. Secretions are aspirated through a bronchoscope from the bronchus draining the region of the suspected tumor. The material thus obtained is smeared on glass slides and stained by the Papanicolaou technique.[10] In the past six months the technique has been improved. When secretion cannot be obtained from the bronchus 2 to 5 c.c. of salt solution are introduced into the bronchus and then aspirated. The salt solution is then examined by the same technique as the bronchial secretions. One hundred eighteen consecutive cases of carcinoma of the lung have now been studied by this method (Table I). Neoplastic cells were found in approximately 90 per cent of these cases. In the same group a positive biopsy was obtained by the bronchoscope in approximately 45 per cent. Neoplastic cells were found in 43 cases in which the bronchoscopic examination was completely negative.

TABLE I. BRONCHOSCOPIC DIAGNOSIS IN 118 CASES OF CARCINOMA OF THE LUNG

	NUMBER	PER CENT
Positive biopsy	52	44
Other suggestive bronchoscopic evidence	23	20
Neoplastic cells found	105	89
Neoplastic cells found; bronchoscopy completely negative	43	36

Table II represents the experience of the senior author with these diagnostic methods in thirty-one patients with carcinoma of the lung explored in the past fourteen months. In eighteen patients a positive diagnosis was made before operation by biopsy obtained through the bronchoscope. In fifteen of these eighteen patients the bronchial secretions were also examined and neoplastic cells found in every instance. In nine patients in whom no biopsy could be obtained, neoplastic cells were found. In these nine patients, almost a third of those explored, the study of the bronchial secretions resulted in positive morphologic *diagnosis prior to operation* (*Fig. 5*).

TABLE II. BRONCHOSCOPIC DIAGNOSIS IN 31 PATIENTS EXPLORED

	NUMBER	PER CENT
Positive biopsy	18	58
Neoplastic cells but no biopsy	9	29
No neoplastic cells and no biopsy	4	13

EXPLORATION

There will always be some patients in whom a diagnosis of pulmonary carcinoma cannot be definitely established without exploration. This was true of four of our thirty-one patients (Table II). In two of these the lesion was resectable and in the other two it proved to be too far advanced for removal. All four had peripheral lesions, two in the right upper lobe and one each in the right lower and left lower lobes. It cannot be too strongly emphasized that every effort should be made to obtain a positive diagnosis before operation. Without such a diagnosis it may be very difficult to determine by inspection or palpation at operation whether or not one is dealing with a malignant tumor. Furthermore, biopsies obtained at the time of operation may fail to reveal tumor tissue, even though a malignant tumor is present. This was illustrated by one patient in our series. He had recovered from an attack of pneumonia, but a residual area of increased density in the left upper lobe could be seen on the roentgenograms. The patient had no symptoms. Bronchoscopic examination was entirely negative, but neoplastic cells were found in saline washings from the left upper lobe bronchus. At operation the medial half of the left upper lobe was firm to palpation. The firmness might well have been due to some chronic inflammatory process. To confirm the diagnosis a biopsy was taken from this area of the upper lobe. Only chronic inflammatory tissue was seen in the microscopic section. A pneumonectomy was performed and a carcinoma found on section of the upper lobe. The biopsy had evidently been taken from the inflammatory tissue around the periphery of the tumor. The finding of neoplastic cells in the salt solution washings was of considerable help in making the decision to perform a pneumonectomy.

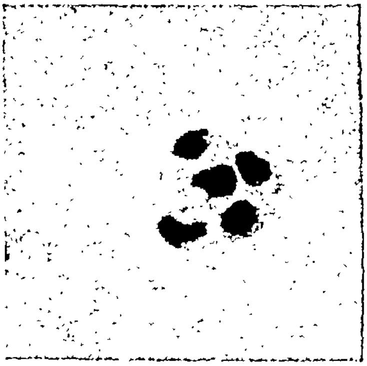

Fig. 5.—Photomicrograph of a group of five cancer cells seen on a smear obtained from the salt solution washing of a bronchus. A biopsy could not be obtained. The patient was explored and a pneumonectomy performed.

Where the diagnosis is certain we feel that exploration should be performed in all patients, unless there is unequivocal evidence of extension of the disease beyond the hemithorax in which the tumor lies, or unless a pleural effusion exists which is bloody, or contains malignant cells. This more radical approach is becoming more generally accepted.[9] The older and more conservative attitude is to refuse operation to patients with *any* type of pleural effusion, those with continuous pain referred to the shoulder or down the arm, or those with Horner's syndrome, left recurrent laryngeal or phrenic nerve palsy.[11] A still more conservative view holds that a lesion is inoperable because of the x-ray appearance.[8] The really debatable issue, concerning whether or not exploration should be done, lies in the group with nerve palsies. Certainly, involvement of the phrenic, recurrent laryngeal, or sympathetic nerves indicates an infiltrating growth which has extended beyond the confines of the lung. This does not mean, however, that the lesion cannot be removed by block dissection including the involved nerve. The phrenic nerve was resected in two of our patients, and the vagus nerve in one. One pneumonectomy was done in which there was a contralateral Horner's syndrome, but no other evidence of involvement outside the hemithorax. This patient died five months after operation. He had extensive metastasis to the right ilium and to the fifth cervical vertebra, which resulted in a pathologic fracture, quadriplegia, and death in twenty-four hours. Probably this patient should not have been operated upon.

In thirty-seven of 243 carefully studied patients with recurrent laryngeal nerve paralysis, no demonstrable cause for the condition could be found.[12] Because of this fact, we have not felt justified in refusing exploration on account of such a paralysis of the vocal cords. Ochsner[9] performed a pneumonectomy on a patient with a palsy of the recurrent laryngeal nerve, and the patient survived operation three years. We have explored one patient with a recurrent laryngeal nerve paralysis, who proved to have an unresectable lesion.

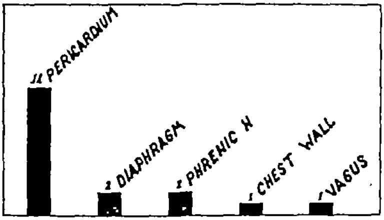

Fig. 6.—Graph of additional resections performed in conjunction with pneumonectomy.

RESECTION

When the chest is opened, the decision to perform a pneumonectomy must be based upon the same principles of cancer surgery which obtain elsewhere. If all visible and palpable tissue involved by the growth can be removed en masse, without leaving any evident malignant tissue behind, we believe that a radical pneumonectomy should be done. The procedure which we have found most effective in increasing resectability has been the intrapericardial ligation of the pulmonary vessels, as proposed by Allison.[1] In eleven of the twenty pneumonectomies performed in this series intrapericardial ligation of the hilar vessels was performed. In ten of these patients it would have been impossible to remove the lung by any other means. In the eleventh patient, because of the proximity of the growth, it was technically more feasible to perform intrapericardial ligation. In four of the ten patients in whom intrapericardial dissection was necessary, the growth was in the left main bronchus, in two it was in the left lower lobe, in three in the right lower lobe, and in one the right middle lobe. In none of the four patients in whom the growth was primarily in the

TABLE III. INCIDENCE OF OPERABILITY, RESECTABILITY AND OPERATIVE MORTALITY REPORTED IN 1947

AUTHOR	YEARS COVERED	NUMBER CASES OBSERVED	CASES EXPLORED		CASES RESECTED		OPERATIVE MORTALITY IN RESECTED CASES (%)
			NUMBER	PER CENT	NUMBER	PER CENT OF EXPLORED	
Ochsner and DeBakey	10	360	210	58	129	61	20*
Rienhoff	13	?	327	?	112	34	21†
Jones	4	196	66	31	39	59	5
Gibbon et al.	1†	56	31	55	21	68	10

*In last five years.
†In last six and one-half years.

upper lobe was intrapericardial dissection necessary. The usual indication was involvement of either the superior or inferior pulmonary vein by the growth, or invasion of the pericardium itself. Fig. 6 shows the other structures which required removal in order to resect the growth completely. In one of the patients in whom the diaphragm was involved, almost half of this muscle had to be removed because of direct extension by growth. In every case all visible and palpable mediastinal lymph nodes were removed. The nodes removed included not only those along the main bronchus of the involved lung, but also the tracheal nodes, and frequently the glands along the inferior margin of the contralateral bronchus. Removal of a portion of the pericardium and ligation of the pulmonary veins at their junction with the left auricle are simple procedures to carry out, and should increase the percentage of pneumonectomies in the patients explored (Table III).

POSTOPERATIVE MORTALITY

The postoperative mortality in recently reported series is shown in Table III. This mortality has shown an encouraging decline in recent years. The lowest mortality has been reported by Jones,[6] who in an addendum to his article, states that he has performed fifty-two pneumonectomies for carcinoma of the lung with only two hospital deaths, an operative mortality of slightly under 4 per cent. We have performed twenty-one resections for primary pulmonary malignancy. Twenty of these resections were pneumonectomies and one was a partial removal of the right lower lobe. The latter operation was for a circumscribed, encapsulated lesion which proved to be malignant on later microscopic study. Two patients died in the hospital following operation. One death occurred shortly after pneumonectomy from a tension pneumothrax. An unsuccessful attempt was made to control this condition by suction through a catheter. The other patient died five weeks after pneumonectomy. He developed an empyema with a bronchopleural fistula, which required open drainage. This was the only empyema in our series. Open drainage was established and the patient's temperature was normal for two weeks prior to death. However, the patient showed progressive weakness and loss of appetite. At autopsy extensive metastasis to both adrenal glands was found. This undoubtedly contributed to the fatal termination. There have been five late deaths from extension of the disease, from three to nine months after operation. Improvement in the care of the patient during and after operation will undoubtedly contribute to a further lowering of the mortality.

CONCLUSIONS

1. Examination of the secretions or saline washings from the bronchus suspected of being the site of a malignant growth will increase the percentage of correct diagnoses prior to operation.

2. The contraindications to exploration are unequivocal evidence of metastatic extension beyond the hemithorax which is the site of the tumor, or the presence of blood or tumor cells in a pleural effusion on the affected side.

3. The limits of operability can be extended in many instances by opening the pericardium and ligating the pulmonary veins flush with the left auricle.

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THE TREATMENT OF INOPERABLE BRONCHIOGENIC CARCINOMA WITH METHYL-BIS

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THORACIC surgeons would be among the first to agree that surgery will never be the complete answer to the cancer problem. Even the combination of an alert medical group and an intensive educational program in the lay public will not diagnose all cancer early enough to be curable by surgery. Particularly is this true in bronchiogenic carcinoma. Early surgery in this form of cancer offers good hope for cure. However, the majority of patients seen are still in the far-advanced stage in which surgical cure is not possible.

X-ray therapy in bronchiogenic carcinoma is chiefly palliative in its action. Recently, however, I have been privileged to see the rough draft of a paper from one of the well-known cancer research hospitals in this country. In this report they list over 400 patients treated by x-ray therapy for cancer of the bronchus. In this group they have several patients alive seven, eight, ten, and even thirteen years after the diagnosis was established and x-ray treatment instituted. Such results following x-ray therapy are the exception rather than the rule.

Because the group of patients with bronchiogenic carcinoma for which surgery offers no hope of cure is so large, a search has been made for some drug which would help in the treatment of these unfortunate patients. I would like to report our results with one of these drugs. We have only been working with the drug for a period of one year, so this will be of necessity a preliminary report and I am sure some of our conclusions will have to be modified later.

Methyl-bis (B-chloroethyl amine hydrochloride) is one of the nitrogen mustard derivatives. During the war the Army Chemical Service experimented with over 300 such mustard gas compounds in its search for effective war gases. Methyl-bis is the first of these derivatives which has been released for widespread investigational use. Its therapeutic efficiency is based upon its remarkably toxic action on rapidly growing cells. Thus its action is first upon rapidly growing cancer cells and second upon the bone marrow. Other toxic effects have not been observed as yet in many patients.

The aim of treatment, therefore, is to administer enough of the drug to stop the growth of the carcinoma cells and yet not enough to depress the bone marrow too much. The drug is extremely toxic and only minute doses can be used. The margin of safety between the therapeutic dose and the toxic dose is very small, so that each patient must be followed very carefully.

Other drugs in this mustard group are under analysis and investigation at the present time and we are hoping that one of these other drugs may be even more effective therapeutically and less toxic to the normal body cells.

Read at the Twenty-Seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

Methyl-bis has been used experimentally since 1942 in treating various types of cancer, chiefly of the Hodgkin's disease and lymphatic group. It is only in the last year that much work has been done in bronchiogenic carcinoma. At the present time 126 different hospitals and clinics in the United States are using Methyl-bis experimentally in various forms of cancer. However, only two series of cases of any size have been reported as yet using Methyl-bis in the treatment of cancer of the bronchus. One of these groups was studied at Memorial Hospital in New York, N. Y., and the other group by us in Memphis, Tenn.

Today I am presenting only our own cases for discussion, but in the future the collected cases from all these institutions will be gathered together in one paper and submitted to the *Journal of the American Medical Association* for publication.

Thus far this work with Methyl-bis has been done under the auspices of the National Research Council's Committee on Growth, headed by Dr. Cornelius Rhoads at Memorial Hospital in New York, and the drug must still be obtained through his office. However it is possible that in the near future the drug will be placed on the market. There is one grave danger in placing such a drug on the market. When cancer can be treated by shots such as Methyl-bis, there will be a temptation with some physicians to use the drug incorrectly. That is, to use it in cases which are suitable for surgical cure. Its use in these cases would only spell disaster for the patients and delay surgery until cure is no longer possible. Therefore, when the drug is distributed for sale we believe the accompanying literature should specifically state that *the drug is not curative* so far as we know, that its effect is only temporary, and that surgery so far offers the only possibility of curing bronchiogenic carcinoma. Its use should be specifically recommended for cases which are not suitable for surgical cure, that is, patients with positive evidence of metastases or direct extension into the mediastinum.

I would like to express one of my conclusions at this point and then justify this conclusion. Methyl-bis is definitely helpful in treating cases of inoperable bronchiogenic carcinoma and it gives clinical improvement in about 70 per cent of such cases for periods of time ranging from six weeks up to six months, after which time the drug must be repeated. The most effective results are secured with the first course of treatment with the drug. Subsequent courses of treatment do not give such noticeable clinical improvement and eventually the drug becomes ineffective.

Up to the present time a total of 500 patients in the United States have been treated with Methyl-bis for various forms of cancer. Of this large group of 500 cases, only forty are reported on bronchiogenic carcinoma in enough detail to justify discussion, and of this forty I would like to present seventeen of our proved cases. The drug is furnished free of charge by Merck and Company at the present time with the stipulation that all cases must be reported in detail to the Committee on Growth of the National Research Council. Because of the extreme care used so far in administering the drug, no serious toxic manifestations have occurred. When these cases are followed with serial x-rays, it is often observed that the tumor becomes stationary for a time and then slowly resumes its growth. It is rare indeed to note any diminution in the size of the tumor following Methyl-bis, but a few such cases have occurred. The drug was tried in all the various histologic classifications of carcinoma of the lung and there did not appear to be much difference in response among the various types of carcinoma of the bronchus. A few such cases which showed little or no improvement after x-ray therapy were definitely benefited by Methyl-bis. The earlier cases in our series were treated by Methyl-bis alone. Later, laboratory work suggested that a combination of Methyl-bis followed by x-ray therapy might be more effective than the Methyl-bis alone. For this reason, the later patients in our series were treated by a combination of Methyl-bis and x-ray therapy. As you can see in our figures, however, this laboratory suggestion was not borne out by clinical data. That is, the patients receiving Methyl-bis alone did as well as those receiving the combination of Methyl-bis and x-ray therapy. As a matter of fact, weight gain was noticed more in the group receiving Methyl-bis alone than in those receiving x-ray therapy and Methyl-bis together. Just as arsenic and bismuth combined appear to be more effective in the treatment of syphilis than either drug alone, so it was reasoned that the combination of x-ray therapy and Methyl-bis would prove more effective than either alone in bronchiogenic carcinoma. This still may be the case, but our early results do not bear this out. It is entirely possible that in our own series we have been using inadequate amounts of Methyl-bis. However, we felt that for a year it would be advisable to adhere to one dosage schedule. Next year we plan to increase the dosage and see the difference in therapeutic results.

At Memorial Hospital they have noticed no difference in results so far in those receiving the standard dose of Methyl-bis as compared with patients receiving double this dose. When the dose is doubled severe bleeding tendencies may occasionally occur. Methyl-bis causes considerable relief of pain in the majority of these patients, but when the pain is severe, x-ray therapy seems to be more effective than the Methyl-bis in relieving the pain. It is possible that the Methyl-bis, or the combination of Methyl-bis plus x-ray therapy causes a definite prolongation of life in these patients. However, the study is too recent to justify such a conclusion as yet. The early results point in this direction.

We do feel that the majority of the patients so treated gain in weight and strength and are able to continue working until nearly the terminal stage of the disease. The end usually comes rather rapidly and it has been very encouraging to us to note that only rarely are narcotics required in the patients treated with Methyl-bis.

Our policy during the coming year will be to administer as much Methyl-bis as the bone marrow will tolerate, as judged by repeated serial blood counts, and to administer as much x-ray dosage as the skin will tolerate.

Following the Methyl-bis injections, over half of the patients exhibit varying degrees of nausea, vomiting, and anorexia which occur a few hours after the administration of the drug and may continue for twenty-four hours. However, this nausea and vomiting are transient and stop when the drug is stopped.

The drug has several advantages over x-ray therapy. It can be produced fairly cheaply and can either be administered as an office procedure or the patient may be hospitalized for a period of four or five days during its administration. It can be used in cases with such widespread metastases that x-ray therapy is of little use. The nausea and vomiting associated with Methyl-bis are usually of shorter duration than the same symptoms following x-ray therapy. We have found that the use of 100 mg. of pyridoxine hydrochloride hypodermically will reduce the incidence of nausea and vomiting. The pyridoxine is usually administered early in the morning and the Methyl-bis is given later in the day.

The results obtained in treating Hodgkin's disease and the lymphatic carcinomas with Methyl-bis are much more dramatic than the results obtained in treating bronchiogenic carcinoma. Our own method of administering the drug thus far has been as follows:

METHYL-BIS TREATMENT ROUTINE

A well-balanced diet with a wide variety of foods, which should include one quart of milk daily and one generous serving of meat fish, or eggs with each meal. Amino acids orally are prescribed if indicated. One multiple vitamin capsule is given twice a day and one ferrous sulfate tablet after each meal and at bedtime. Smoking is prohibited. Many of these patients have an associated bronchiectasis due to the carcinoma and the symptoms of the bronchiectasis are usually helped when the smoking is stopped. A postural drainage routine is helpful in such cases. Aspirin will usually suffice for discomfort or actual pain in most cases. Daily sun baths are advised when the weather permits to keep the patient busy and also for the mild tonic effect. Incidentally, the sun baths seem to be a morale builder as well. Moderate exercise and recreation are helpful but the patient is advised to avoid overfatigue. He may work if he feels able.

A follow-up history, physical examination, complete blood count, and either fluoroscopic or x-ray examination of the chest is taken every two weeks. Blood transfusions are used if indicated, as the Methyl-bis is quite toxic to the bone marrow. However, using the dosage recommended, blood transfusions are only necessary in 10 to 20 per cent of the patients treated.

ADMINISTRATION OF METHYL-BIS

The drug is supplied in 10 mg. vials as a dry powder. The patient is hospitalized for five days and is given 0.1 mg. of Methyl-bis per kilogram of body weight intravenously once daily for four days. This course of treatment can be repeated every two or three months or more often if necessary. The drug must be used immediately after it is made up in solution. Ten cubic centimeters of sterile saline are injected into the 10 mg. vial of Methyl-bis and the appropriate amount of drug is withdrawn and injected. The vial is then discarded. Immediately following the Methyl-bis injection the needle is left in place and another syringe containing 10 c.c. of sterile saline is then injected through the same needle in an attempt to prevent thrombosis in the vein.

A still better method of administration is to start 1,000 c.c. of sterile saline going intravenously and then inject the appropriate dose of Methyl-bis into the tubing with a No. 22 gauge needle.

Lately we have treated some patients by giving one dose of the Methyl-bis every two weeks, and apparently have obtained similar results as with the foregoing method. By giving the drug once every two weeks it can be given in the office without hospitalizing the patient. Larger doses than the above amount can be given but are more hazardous.

The action of the Methyl-bis on the cancer cells and on the bone marrow is in many ways similar to the action of x-rays. In the experimental animal and in human beings as well, larger doses result in a lymphopenia, a granulocytopenia, a thrombocytopenia, and a moderate anemia. These effects are directly porportional to the dosage of Methyl-bis given. Disappearance of mitotic activity is noted in both the bone marrow and in the cancer cells following the injection of Methyl-bis. Continued large doses of Methyl-bis cause a complete depletion of the bone marrow and eventual aplasia. Experimentally, it can be demonstrated that the Methyl-bis acts directly on the structure of the chromosomes and this abnormality in the chromosomes can be transmitted from ovum to ovum for several successive generations. So far as we know now the therapeutic efficiency of the nitrogen mustards is no greater than that of x-ray therapy.

RESULTS

In all we have now treated thirty-one cancer patients with Methyl-bis. Twenty-five of these patients had bronchiogenic carcinoma. Of these, three were adenocarcinoma, five were squamous cell carcinoma and seventeen were undifferentiated cell carcinoma.

Although we have thus far treated twenty-five cases of bronchoigenic carcinoma with Methyl-bis, we are only reporting in detail seventeen of these cases in this report as only these seventeen have a definite pathologic report and follow-up study sufficiently complete to be of statistical interest.

In addition to these twenty-five bronchiogenic carcinoma patients, we have treated one patient each with carcinoma of the cervix, carcinoma of the esophagus, carcinoma of the ovary, adenocarcinoma of the testis, carcinoma of the nasopharynx, and melanosarcoma. Most of the patients in the above miscellaneous group had multiple pulmonary metastases, which is the reason they came to our attention.

Five of the six patients listed above with miscellaneous carcinoma elsewhere in the body received definite clinical improvement following the Methyl-bis administration, but again the improvement was only temporary and in a period of a very few weeks or months the tumors again showed signs of growth and further metastases then occurred. One rather striking case was that of an elderly man with two large tumors on the anterior chest wall, one on either side. The one on the right was completely excised surgically including the rib and parietal pleura involved. The pathologic diagnosis was a lymphosarcoma. As an enlarging tumor was then apparent in the abdomen further surgery seemed useless. Methyl-bis was given and three days later the tumor on the left chest had completely disappeared. This tumor was approximately the size of half an apple.

Methyl-bis is a useful drug, but so far as we know is not curative. One indirect benefit from the drug is that these patients are observed more carefully and symptoms can be treated as they arise. This in itself helps in raising the morale of these patients who were formerly told to go home and that nothing else could be done for them. Another advantage of the Methyl-bis is that it is a powerful expectorant, and this action usually results in making the patient's breathing easier and in decreasing his wheezing. Some of these patients even spit up bits of the tumor during the administration of the Methyl-bis. Naturally, mortality statistics in this group of cases are not encouraging. If our diagnosis is correct, our eventual mortality will be 100 per cent.

REPRESENTATIVE CASES

I would like now to present brief histories on four representative patients who were treated early in our series with Methyl-bis alone and who showed definite clinical improvement following the use of the drug.

CASE 1.—Mrs. B. F., aged 68, housewife, had a squamous cell carcinoma in the bronchus with metastases to both pleural spaces and to the seventh left rib. She had noticed palpitation for several years and during the past few weeks had noticed dyspnea, slight cough, and left chest pain. The hemothorax on the left was aspirated on numerous occasions and large amounts of bloody fluid were obtained. The fluid, when centrifuged, revealed cells suspiciously like cancer cells but the pathologist was unwilling to make a definite diagnosis on these few cells.

On Aug. 24, 1946, the seventh left rib was removed and pathologic examination showed definite squamous cell carcinoma. She was given 5.8 mg. of Methyl-bis intravenously on August 28, 29, 30, and 31 and she noticed repeated vomiting each time for one day following the injections. Two months later she was doing housework and felt well. Her breathing was comfortable, she had no fever, and she had gained five pounds in weight. Two weeks later she had gained another three pounds and her strength was improving.

On Nov. 11, 1946, 300 c.c. of clear amber fluid were aspirated from the left chest and since that time no more fluid has been present in the left chest. Several taps since then have yielded no fluid.

She was given a second course of 6.5 mg. of Methyl-bis on Dec. 7, 8, 9, and 10, 1946. Pyridoxine was administered this time and her vomiting was a little less than with the first course. The patient was in much better condition now than she was three months previously.

In January her general condition was still excellent and she was doing her housework but taking occasional aspirin for pain.

In March, 1947, she was given her third course of Methyl-bis. She received 6.5 mg. on Feb. 17, 19, 24 and March 10 and 29, 1947. At that time she weighed fourteen pounds more than she did when originally seen and she was still doing her own housework. No narcotics are required. She is still alive.

CASE 2.—Mr. D. F., aged 58, had pneumonia five times since childhood. The past twelve years he had been treated elsewhere for asthma. He had had a cough for several years and blood-streaked sputum intermittently the past few years with two severe hemoptyses, and he had also noticed shortness of breath during this time. During the past three years he had two typical attacks of coronary thrombosis. The past few months he had not worked.

In July, 1946, an x-ray showed a tumor in his chest. Indirect laryngoscopy revealed complete paralysis of the left vocal cord. Bronchoscopy that same month showed a tumor in the left upper lobe bronchus and in the left main bronchus. A biopsy of this tumor showed a squamous cell carcinoma of the bronchus, poorly differentiated. A ray fungus was also found in the bronchoscopic sputum, but this was not definitely identified as actinomycosis.

He was given 9 mg. of Methyl-bis intravenously on July 24, 25, 26, and 27, 1946. During the administration of the drug he raised much sputum and also coughed up bits of the tumor. He vomited a few times. Two months later he had gained ten pounds in weight and his sputum was decreasing and now clear. He was able to work half a day, managing a coal yard. There was no change in the size of the tumor during those two months. Three weeks previously he had a mild cerebral apoplexy but recovered with a slight residual weakness in the left arm and left leg.

A second course of Methyl-bis was given, 9.5 mg. being administered on Nov. 18, 19, 21, and 22, 1946. An x-ray at this time suggested that the tumor had shelled out a large central cavity 7 cm. in diameter.

In January, 1947, he weighed twenty pounds more than he did before Methyl-bis was started, and was working full time. He occasionally noticed blood streaking. In February he had constant dyspnea and had an hemoptysis of two or three ounces.

On March 11, 1947, his physical condition appeared surprisingly good considering the size of his tumor, and he was given another 9.6 mg. of Methyl-bis intravenously.

On April 21, 1947, he was admitted to the hospital with uremia. A few days later he fell out of bed and broke his hip and died quietly three days after this. No autopsy was permitted. His x-ray showed little change in the size of the chest tumor.

We believe that Methyl-bis probably prolonged his life and made him more comfortable. He was given an occasional Dilaudid tablet for his hemoptysis, but little medication was required for pain.

CASE 3.—Mr. H. B., aged 54, stated he had pneumonia several years ago, followed by flu. He had felt poorly since January, 1946; that is, he was weak, nervous, noticed easy fatigue, and had a moderate weight loss. He was put on an ulcer diet because of his stomach complaints. During the past several years he occasionally noticed blood-streaked sputum and some shortness of breath, with moderate cough and sputum.

X-ray in July, 1946, revealed a tumor in the right upper lobe with some increase in atelectasis, and he had several hemoptyses. A gastrointestinal series showed no pathology.

Bronchoscopy was performed on three separate occasions and each time involvement of the lower trachea, right upper lobe bronchus, and carina by an ulcerating lesion was seen. The first two bronchoscopic biopsies were indeterminate and sputum examinations were negative for acid-fast bacilli. We felt that if this were a carcinoma it was inoperable because of involvement of approximately one inch of the trachea. Hoping that it was a pulmonary tuberculosis, a right phrenic crushing was done on March 14, 1946.

The last bronchoscopy on July 17, 1946, enabled us to make a definite diagnosis, as the biopsy at that time revealed an undifferentiated bronchiogenic carcinoma. In addition, one sputum showed Monilia.

He received 6.9 mg. of Methyl-bis intravenously on July 22, 23, 24, and 25, 1946. He vomited once or twice. Four months later he felt better and stronger and had gained seven pounds in weight. No further hemoptyses had occurred. He was given three transfusions for a secondary anemia. A month later he noticed some weakness of his voice and indirect laryngoscopy revealed complete paralysis of the right vocal cord.

X-ray at this time showed some regression of the atelectasis and the tumor appeared smaller. In October, 1946, he received three more transfusions for his secondary anemia. He was constantly hoarse and wheezing and had some dyspnea on exertion, but he was ambulatory and gaining weight. He now weighed fourteen pounds more than he did before Methyl-bis therapy.

On Nov. 12, 1946, his voice was almost normal at times, he had gained three more pounds, and an x-ray of his chest showed a central softening of the tumor. A second course of Methyl-bis was given. He received 7.2 mg. on Nov. 21, 22, 23, and 24, 1946, with pyridoxine earlier each day. Each time there was much less vomiting than with the first series.

In January, 1947, he began a rapid downhill course. He found it difficult to swallow, was short of breath, and lost five pounds in weight. Enlarged lymph nodes appeared about the right clavicle and a small right pleural effusion made its appearance. He died in February, 1947, with complete paralysis of both vocal cords. A tracheotomy had been performed, but this gave little relief. A bronchoscopy had been performed through the tracheotomy opening in an attempt to remove enough of the tumor from the left bronchus to give him an airway. Bleeding occurred and the patient asphyxiated soon after the bronchoscopy.

Autopsy was performed and a tumor was found at the carina, 15 cm. in diameter which extended up the trachea almost to the tracheotomy opening. This tumor completely occluded the right bronchus. There was extreme enlargement of the tracheobronchial lymph nodes and one metastatic nodule in the left adrenal gland. There was evidence of recent hemorrhage into the left bronchus.

This patient was relatively comfortable and gained in weight until one month before his death and only occasional codeine was required for discomfort.

CASE 4.—Mrs. E. M. B., 50 years old, had noticed a cough for the past nine years since a "strep throat" at that time. The cough was nonproductive, but worse the past year. There had been constant intractable pain in the right arm more recently.

In July, 1946, she noticed several kernals over her body and at our first examination we saw six of these nodules present. She had a low-grade fever and fluoroscopy revealed paralysis of the right diaphragm.

X-ray of the chest showed a lemon-sized tumor in the right paramediastinal region and excision of one of the nodes on her scalp revealed evidence of a metastatic bronchiogenic carcinoma.

Five milligrams of Methyl-bis was given intravenously Sept. 6, 7, 8, and 9, 1946. She vomited several times after each dose. The following months she gained a little weight. Her dyspnea was less and her wheezing disappeared. The pain was not as severe.

X-ray showed no growth in the bronchiogenic carcinoma and the metastatic nodes remained the same size. Radium needles were inserted in a metastatic nodule on the tongue and caused almost complete disappearance of this nodule. She was ambulatory.

Another course of Methyl-bis was given Nov. 4, 6, 7, and 9, 1946. At each injection she received 4.8 mg. of the drug with much vomiting after each dose. She is still alive and ambulatory part of the time and requires no narcotics.

In January, 1947, she had lost fifteen pounds since the original examination. She had a temperature of 99.4° F. in the afternoon, and she was up several hours a day but was weaker. The nodules over her body were larger. She required no opiates but took aspirin occasionally for pain and used a heat lamp.

TABLE I. SEVEN PATIENTS STILL ALIVE

METHYL-BIS ALONE (2 EARLIER CASES)			METHYL-BIS PLUS X-RAY THERAPY (5 LATER CASES)		
TYPE CARCINOMA	TIME SINCE BIOPSY DIAGNOSIS	TIME SINCE ONSET OF SYMPTOMS	TYPE CARCINOMA	TIME SINCE BIOPSY DIAGNOSIS	TIME SINCE ONSET OF SYMPTOMS
1 squamous cell carcinoma (doing housework)	9 mo.	12 mo.	1 squamous cell carcinoma (working)	7 mo.	4 yr.
1 undifferentiated type carcinoma (doing housework)	10 mo.	20 mo.	3 undifferentiated type carcinoma working	5 mo.	6 mo.
			Doing housework	3 yr.	3½ yr.
			Ambulatory	3 mo.	6 mo.
			1 adenocarcinoma (doing housework)	5 mo.	17 mo.

Table II. Ten Patients Who Have Expired

METHYL-BIS ALONE (5 EARLIER CASES)			METHYL-BIS PLUS X-RAY THERAPY (5 LATER CASES)		
TYPE CARCINOMA	TIME SINCE BIOPSY DIAGNOSIS	TIME SINCE ONSET OF SYMPTOMS	TYPE CARCINOMA	TIME SINCE BIOPSY DIAGNOSIS	TIME SINCE ONSET OF SYMPTOMS
2 squamous cell carcinoma patients	9 mo.	12 yr.	1 squamous cell carcinoma patient	7 mo.	8 mo.
	5 mo.*	2½ yr.			
3 undifferentiated type carcinoma patients	7 mo.	13 mo.	4 undifferentiated type carcinoma patients	9 mo.	2 yr.
	7 mo.	2 yr.		4 mo.	10 mo.
	5 wk.†	2 mo.		4 mo.	7 mo.
				4 mo.	6 mo.

*Terminal coronary attack.

†Died five weeks after exploratory thoracotomy, with complicating hemothorax.

Table III. Clinical Improvement (Temporary)

	METHYL-BIS ALONE (7 CASES)	METHYL-BIS PLUS X-RAY THERAPY (10 CASES)
Weight gain	70% (4, 10, 14, 14 and 20#)	40% (highest gain 7#)
Decrease or cessation of hemoptyses	42%	10%
Cessation of hemothorax	14%	10%
Clearing of atelectasis	28%	10%
Disappearance of congestive heart failure (only 1 pt. had this)		10%
Subsidence of pleural effusion (only 1 pt. had this)		10%
Decrease in cough, sputum, wheeze, and dyspnea	70%	60%
Decrease in sepsis (chills, fever, etc.)	70%	40%
Increase in strength and ambulation	70%	90%
Decrease in pain (only 1 required morphine terminally)	70%	70% (only 2 required morphine terminally)

CONCLUSIONS

We believe that the proper treatment of bronchiogenic carcinoma at the present time is pneumonectomy if at all feasible. If surgery is not warranted because of extension of the carcinoma into the mediastinum or of the presence of distant metastases, then we believe a combination of Methyl-bis injections plus x-ray therapy offers the best aid to the patients. Methyl-bis is a useful drug, but it is extremely toxic and it must be administered with care. Studies must be repeatedly made on the patient's blood to follow the state of the bone marrow. When the drug is placed on the market for sale we strongly advise that the literature accompanying the drug state explicitly that surgery is still the only curative therapy in bronchiogenic carcinoma and that Methyl-bis should be reserved for cases not suitable for surgical attack.

We would like to express our sincere thanks at this time for the wholehearted cooperation and advice given us by Dr. Cornelius P. Rhoads and Dr. David Karnofsky of Memorial Hospital in New York City.

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DISCUSSION

DR. MICHAEL E. DEBAKEY, New Orleans, La.—My experience with this method of therapy is so limited that I should prefer to direct comments not toward the method but toward the general problem which it raises; that is, accurate and critical evaluation of any form of therapy. We all tend to be optimistic about any new method. Perhaps this is basically desirable. I know from my own experience how easy it is to become enthusiastic about any new form of therapy which in the early phases of its application seems to lead to clinical improvement. It is particularly easy to become enthusiastic when you are yourself interested.

I would not wish my remarks to be construed as critical of the evaluation which the essayist has made of the results of this form of therapy. He has properly emphasized the fact that it is not curative, that it has been used only in hopelessly inoperable cases, and that clinical improvement is about all that it seems to provide. It is important to remember, however, that clinical improvement is on the whole a variable and unreliable criterion to employ in the evaluation of any new form of therapy, especially if the agent is administered parenterally. Too many other factors, alone or in combination, may bring about similarly good results. The interest shown by the physician in the patient, the patient's own strong desire to recover, which is particularly evident in incurable disease, and dietary and supportive measures all play a role, and the specific agent employed must be assessed against them by the careful use of controls.

History is full of classic examples of how easy it is to be misled in these circumstances. About ten years ago, for instance, injectable agents became widely popular in the treatment of peptic ulcer. Numerous reports were published indicating good results from them. We also had excellent results from them, but unfortunately we had equally good results in the control series in which the injections consisted only of sterile water.

DR. CHESTER MOEN, Chicago, Ill.—This is a brief résumé of ten patients with proved carcinoma of the lung who have been treated with nitrogen mustard this year at Wesley Memorial Hospital.

It so happens that the first five patients appearing on this slide had squamous cell carcinoma and showed no response while the last five had undifferentiated carcinoma and showed some response.

Among those that showed response to Methyl-bis, there was one case which was particularly dramatic. This patient had a complete atelectasis of the left lung, a fixed vocal cord, a lot of pain and cough, and a septic type of fever. Three days after the administration of this drug, the fever went away and remained normal. Six weeks later the pain had disappeared and the patient had gained ten pounds in weight. However, after two months the pain recurred and in spite of repeated injections of the nitrogen mustard, he has not improved.

Two other patients had large metastatic masses at the base of their neck. Ten days after the administration of this drug, the masses were definitely smaller and softer; the circumference at the base of the neck measured as much as two inches less. This regression continued for about a month. However, after five weeks it was noted that the tumor was progressing. Biopsies were taken before and after the administration of the nitrogen mustard but we were not able to detect any change in the anaplastic picture. In none of these cases was there any change on the chest x-ray.

In view of this early but brief response, one is led to suspect that the benefit derived from nitrogen mustard may, perhaps, be due to its effect upon the surrounding inflammatory tissue rather than upon the tumor tissue itself. We have had no bad effects from giving this drug; however, it is advisable to wait a week or two after thoracotomy before giving it, because of the brief but sometimes severe leucopenia which follows.

DR. FREDERICK R. HARPER, Denver, Colo.—I would merely like to add ten cases to the series.

I visited Dr. Skinner and Dr. Carr in Memphis in December. At that time they suggested this method of treating inoperable carcinomas of the lung. I obtained enough to treat ten patients, and I will just report the results in the ten I treated.

They were all inoperable carcinomas, proved either by biopsies of cervical lymph nodes or thoracotomy. Three of the patients are dead. In one of these, autopsy showed some necrosis of the liver which might have resulted from the toxic effects of the drug.

Seven patients are still alive. Two have obvious metastasis still present. In one of the cases in which there was lymph node involvement from which a biopsy was obtained, after treatment the lymph nodes disappeared, although the tumor in the lung is still present.

There were two cases in which there was a rather unusual phenomenon. These patients coughed up large plugs. Examination of these plugs by a pathologist showed them to consist of necrotic tumor tissue. In one case there was a rather striking clearing of the atelectasis after administration of the drug.

In all of the cases it seemed as though the cough had lessened, the pain was less severe, and the patient was clinically improved.

The main recommendation I could make for the drug is the fact that the patients felt symptomatically and psychologically better in that something was being done for them when they had an inoperable carcinoma.

DR. EDWARD E. AVERY, Hines, Ill.—I would like to report another nine cases, at Hines Hospital. We have had the drug for only three months.

Six of the patients had definite beneficial results in the relief of dyspnea and cough, and gain of weight. Four of the patients were on morphine every three hours. Following treatment, two of the patients needed no medication and the other two took one hypo for sleep at night.

There were two dramatic results. One patient was in complete anuria; he was given a course of Methyl-bis and started to urinate—why, we do not know. Another patient had superior vena cava obstruction with largely dilated neck veins and had extreme pain. Following a course of Methyl-bis, signs of his obstruction disappeared; and he was relieved of pain.

The drug has definite dramatic appeal to the patients, and the psychogenic point should be re-emphasized. Already a whispering campaign is starting, and the patients are asking for this "new, poison gas treatment."

DR. OSLER ABBOTT, Atlanta, Ga.—I would just like to mention five cases in which we have used this drug, because it emphasizes Dr. DeBakey's remarks to such an extreme degree.

We purposely made a point of not giving any additional psychotherapy with the drug. We saw absolutely no beneficial effects from the period of its use. In one patient a severe lymphopenia occurred, and lasted for several weeks. This patient became nauseated under treatment and continued to have this severe complaint until the time of death, approximately ten weeks later.

We have come to the feeling in this very small group that we would rather confine the use of the drug to the Hodgkin's cases until we have a larger supply.

DR. EDWARD F. SKINNER, Memphis, Tenn.—I would like to thank the discussants, especially Dr. DeBakey. His comments are most pertinent.

It is a new drug. We are not trying to detail it here. We just thought our reports were interesting enough to warrant further discussion.

NONMALIGNANT INTRATHORACIC LESIONS SIMULATING BRONCHIOGENIC CARCINOMA

REPORT OF 30 OPERATED CASES

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INTRODUCTION

THE increasing number of cures that are being effected by total removal of primary bronchiogenic carcinoma places a great obligation upon the physician to establish the diagnosis early enough to permit complete excision of the tumor. In those cases in which the malignancy is visible with the bronchoscope, the diagnosis can be made with certainty by obtaining a biopsy under direct vision. However, when carcinoma of the lung arises in a branch bronchus which cannot be seen at bronchoscopy, the early diagnosis may be extremely difficult. Too often, the physician permits an operable "peripheral" primary bronchiogenic carcinoma to become inoperable by waiting until the diagnosis is definitely established before referring the case to the surgeon. Too often the surgeon hesitates to perform pulmonary resection for fear of doing an "unnecessary" operation. Therefore, this study of peripheral pulmonary lesions simulating bronchiogenic carcinoma has been undertaken in order to evaluate the eventualities should the pulmonary condition be proved nonmalignant at operation. This report represents a review of thirty operated cases in which, although carcinoma of the lung was suspected, various benign lesions were found.

PRESENTATION OF THE CLINICAL PROBLEM

In primary bronchiogenic carcinoma, the complexity of the clinical problem is directly dependent upon the percentage of cases in which a positive diagnosis cannot be made by bronchoscopy. In spite of the fact that the tumor may be located close to the hilum, we arbitrarily classify all cases as "peripheral" where the lung cancer arises beyond the limits of bronchoscopic diagnosis. Although the reports in the literature state that from 60 to 75 per cent of the cases of bronchiogenic malignancy are visible at bronchoscopy, in our experience less than one-half the cases could be diagnosed by this examination. During the past six years we have seen over 300 patients with primary bronchiogenic carcinoma. Even with the use of the right-angled mirror introduced into the bronchoscope and "blind biopsies," a positive bronchoscopic diagnosis of carcinoma was made in only 45 per cent of the patients. In the remainder, the diagnosis was made by an analysis of all the clinical findings. The seriousness of this problem is brought out by the fact that only one-sixth of all our cases were operable. It is true that in many instances the diagnosis was not made early because the classical signs and symptoms of primary pulmonary malignancy were misinterpreted by the physicians who first saw these patients. How-

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ever, in a large percentage of cases the chest roentgenograms demonstrated the lesion to be peripheral and so, because of lack of a positive diagnosis of cancer, the tumor was allowed to become inoperable. The only hope of cure of these peripheral tumors is complete excision while the neoplasm is still confined to the lung. This can be accomplished by exploration in all patients where a peripheral lung cancer is a strong possibility. We have gradually adopted this plan of attack and are convinced that it offers the only chance for cure in these peripheral malignant tumors. If this surgical philosophy is pursued, the benign lesions will be removed also. The common attitude is to regard the removal of a nonmalignant pulmonary lesion as a "surgical error"; in fact, this was our original belief. However, as we discovered more and more of these benign conditions at surgery, we were impressed with the fact that the great majority of the patients were cured by surgical excision. On the other hand, a few of the patients were not improved. It seemed valuable, therefore, to review our experiences with these nonmalignant conditions, not only to arrive at better standards of differential diagnosis but to evaluate the results of the surgical treatment.

The benign group of cases that simulate peripheral pulmonary malignancy is composed of a wide variety of conditions. The thirty cases reviewed in this study represent the most common examples of the type of case that may be found, but do not include all the eventualities present in the wide field of pulmonary disease, as shown in Table I. This study, therefore, is not intended as a statistical report, because this series is not large enough to include all types. The important clinical findings of the benign group of cases are listed together (Table V) so that they may be more simply compared with similar data in a representative group of malignant cases with negative bronchoscopy (Table VI). After a general consideration of the clinical and roentgenological findings, the individual categories of the nonmalignant cases are discussed separately.

TABLE I. DIAGNOSIS OF THIRTY BENIGN CONDITIONS SIMULATING BRONCHIOGENIC CARCINOMA

INFLAMMATORY		BENIGN TUMOR			DEVELOPMENT	
Lung abscess	6	Adenoma		3	Cysts	3
Tuberculosis	5	Lipoma		2	Thyroid	1
Pneumonitis	3	bronchial	1			
Bronchiectasis	3	pleural	1			
Granuloma	1	Fibroma		1		
Echinococcus	1					
Silicosis	1					
Totals	20			6		4

DIAGNOSIS

Certain clinical and roentgenologic findings are important in arriving at a presumptive diagnosis of peripheral carcinoma of the lung. We have taken a composite of these findings from the reports in the literature and have compared them with similar data obtained from a study of this series of benign cases.

TABLE II. SEX INCIDENCE

	MALE (%)	FEMALE (%)
Benign	53 (16 cases)	47 (14 cases)
Malignant	85	15

Sex Incidence.—Primary carcinoma of the lung is primarily a disease of the male sex, in which the ratio of males to females afflicted is approximately 5:1. In the cases of the nonmalignant group of this series, the number of females was only slightly less than the number of males; thus, the number of females in the benign group is markedly increased over those in the malignant group.

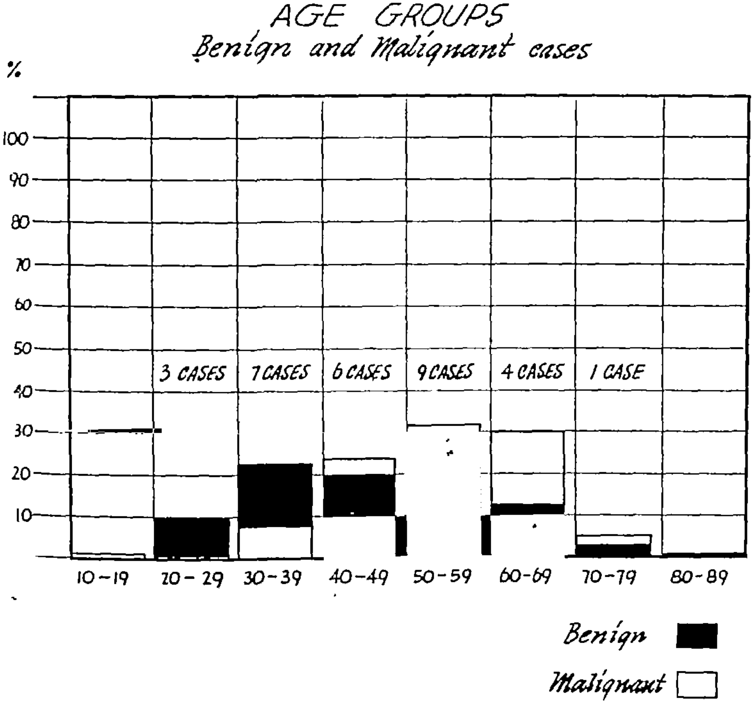


FIG. 1.

Age Incidence.—Bronchiogenic carcinoma is found in the second to the ninth decades of life, but 85 per cent of the cases occur between the ages of 40 and 69 years. In the cases of the nonmalignant series, we have a lesser range of ages, the youngest being 29 and the oldest 70 years of age. Two-thirds of the benign cases occurred in the 40 to 69 age group. Of course, a larger series of benign cases might appreciably change this figure and show a greater preponderance of younger persons; however, it is significant in the cases that we have studied that there is a great similarity of the age groups of the malignant and the nonmalignant cases. (Fig. 1.)

Duration of Symptoms.—In the group of thirty benign cases, the duration of symptoms varied from two months to almost ten years. The great majority were of less than six months' duration. It is impossible to compare these figures with their wide variation to those of bronchiogenic carcinoma since the duration of symptoms depends on the diagnostic skill of the physician who first sees the case. Most cases of carcinoma are not diagnosed under six months. We have recently successfully performed a pneumonectomy on a 65-year-old male with bronchiogenic carcinoma who had symptoms over a period of eight years and have seen several operable cases with histories of symptoms from one to two years. Although no hard and fast rule can be made, one can assume, if the symptoms persist for more than nine months without the obvious signs of carcinoma, that the lesion is likely to be benign.

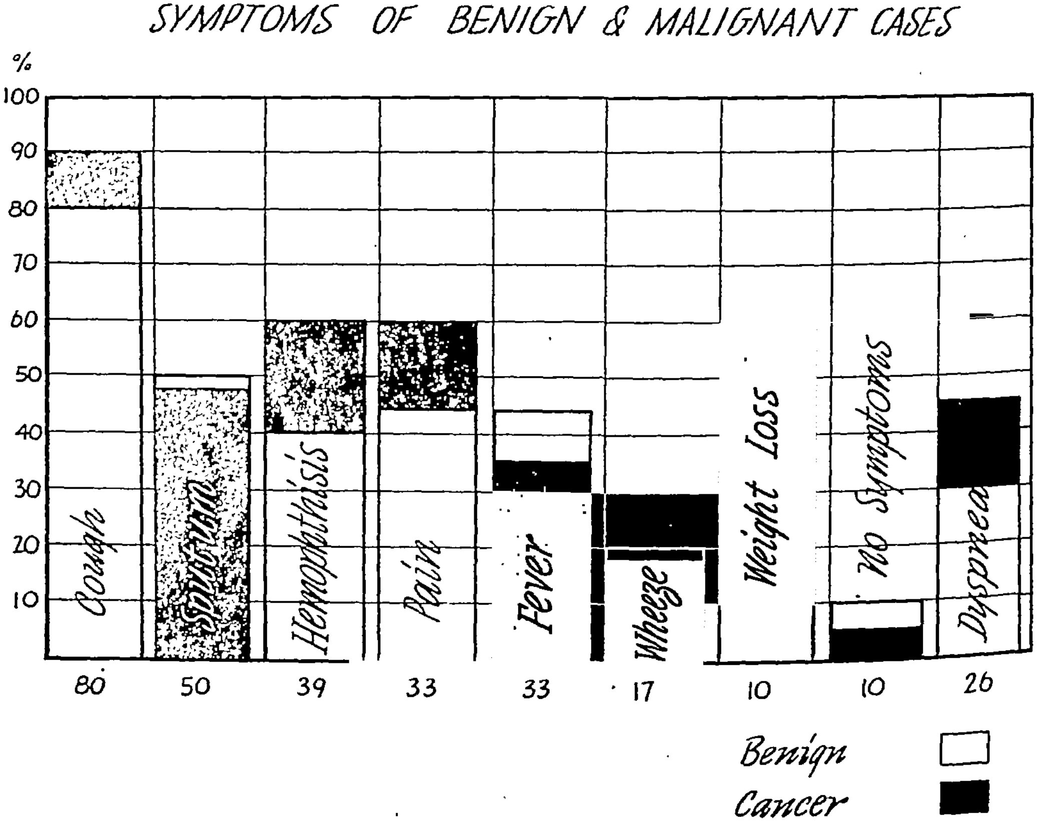


Fig. 2.

Symptomatology.—A comparison of the symptoms of the benign and the malignant cases shows a striking likeness (Fig. 2). Although it does not seem profitable to pursue the comparison of small differences in the figures, it is significant that cough, expectoration, and wheezing were found in the same relative percentages in both groups. In evaluating the symptomatology, some emphasis must be placed on weight loss, hemoptysis, pain, and dyspnea, which were more marked in the malignant cases than in the benign group. It is of interest to remember that 5 per cent of the early cases of bronchiogenic carcinoma have been found during the asymptomatic phase during routine x-ray examination.

In our small group of benign cases, 10 per cent were discovered during routine chest x-ray studies. In a recent report of intrathoracic tumors picked up by routine roentgenologic study of navy personnel,[1] five out of twenty-three tumors so found proved to be malignant. This study was made on a relatively young group of persons in which the oldest was 44 years of age and does not represent a large scale study of the same age group, as do the cases in this report. These *facts point out, as has been reported previously, that with the increasing use of* the periodic x-ray examination, many cases of asymptomatic primary carcinoma will be discovered. The important lesson to be gained from studying the symptomatology of the malignant and the benign groups is not the slight differences of these pooled statistics, but that in general the symptoms are really very similar. Certainly, on symptomatology alone, the differential diagnosis of these two groups of cases cannot be made.

Physical Examination.—The physical findings are so varied that it does not seem advisable to catalogue them. The physical examination of the chest shows few physical signs for either the benign or malignant lesion. In both the benign and malignant cases, the findings depend upon (1) the bronchial obstruction and (2) the amount of infection. Therefore, we must not rely on the physical signs to differentiate a localized pulmonary lesion. If, however, the physical signs change from lobe to lobe or spread to the opposite lung, then a migratory inflammatory condition is present rather than a pulmonary cancer.

Sputum Examination.—Careful examination of the sputum must be carried out in every case of suspected peripheral carcinoma of the lung. The most important diagnostic procedure is to rule out pulmonary tuberculosis with an "open" type of lesion. If the patient is raising considerable amounts of mucoid or mucopurulent sputum, *then a series of negative concentrated sputum examinations* for acid-fast bacilli may be taken as a reasonably reliable standard in ruling out "open" pulmonary *tuberculosis. However,* when the sputum is scanty or nonexistent other methods must be employed. Sputum obtained by gastric lavage or *that aspirated from the bronchus draining the pulmonary lesion* at bronchoscopy is an accurate source for the detection of the tubercle bacilli. If no sputum is available at bronchoscopy, then a few cubic centimeters of saline may be introduced into the branch bronchus. This bronchus is "lavaged" with the saline *solution, which is then aspirated for* bacteriologic examination. Such specimens are studied not only for tubercle bacilli but for fungi and the predominating pyogenic organisms.

The sputum aspirated from the draining bronchus at bronchoscopy should also be studied for malignant cells after the staining method described by Papanicolaou.[2] The success of this test is based on the fact that tumor cells are dislodged from the parent tumor and are detectable in the sputum with this stain. Herbut and Clerf[3] have reported considerable success in diagnosing peripheral carcinoma with this method. Although our own experience with this stain is limited, we believe that the early results commend a wider use of this technic. The procedure is somewhat time consuming and the pathologist needs considerable experience to become proficient in the interpretation of the smears.

It should be emphasized strongly that although the finding of malignant cells in the sputum proves the diagnosis of carcinoma, a negative test does not rule out this possibility.

ROENTGENOLOGIC DIAGNOSIS

When the sputum examination has failed to reveal either a specific infection or malignant cells, then the diagnosis in cases of early peripheral pulmonary malignancy rests mainly on the correct interpretation of the chest roentgenograms. The x-ray findings (Table III) may be classified into five types: (1) masses in the parenchyma of the lung, free from the hilum or parenchymal masses; (2) atelectasis; (3) central masses; (4) abscess cavities; and (5) cystlike structures. Roentgenologic studies of the primary pulmonary malignancies show a relative preponderance of hilar masses as contrasted with the distal ones. With hilar masses, the bronchoscopy is more likely to show the suspected tumor. Atelectasis, too, is a common finding. Cystlike structures and abscess cavities are less frequently observed in malignant pulmonary lesions. In the thirty benign cases in this series, there were fifteen parenchymal masses, seven atelectases, five central masses, two abscesses, and one cystlike formation.

TABLE III. SUMMARY OF X-RAY FINDINGS

PARENCHYMAL MASSES		ATELECTASIS		CENTRAL MASSES		ABSCESS CAVITIES	CYSTS
Abscess	5	Benign tumors	1	Cysts	2	2	1
Benign tumor	4	Bronchiectasis	2	Pneumonitis	1		
Tuberculosis	4	Tuberculosis	1	Bronchiectasis	1		
Pneumonitis	1	Granuloma	1	Silicosis	1		
Thyroid	1	Pneumonitis	1				
		Echinococcus	1				
Total	15		7		5	2	1

We have relied mainly on posteroanterior upright, lateral, and oblique films, supplemented with a careful fluoroscopy in each case to note shift of the lesion and diaphragmatic movement. Potter-Buckey grid films are important to show possible bone destruction. Planograms or tomograms have not proved as helpful as we hoped when this method was first introduced. They distinguish between a solid mass and one with central cavity formation and they show the exact location of the lesion, demonstrating whether or not the mass is fixed to the rib cage, the sternum, etc.; however, the great weakness of these special films is that they do not show the nature of the mass.

Similarly, Lipiodol studies of the bronchial tree may show the presence of a bronchial block, but they do not tell the nature of the block and so give only a presumptive diagnosis. In case of atelectasis when the bronchoscopy is negative, the presence of bronchiectasis may be proved by the simple introduction of the radio-opaque oil. We employ bronchograms mainly to demonstrate the presence of bronchiectasis. It must be remembered that a bronchogram that does not demonstrate a bronchial block has not at all ruled out the presence of a bronchiogenic carcinoma. A diagnostic pneumothorax is helpful only in eliminating the possibility of lesions of the chest wall, mediastinum, and diaphragm, provided that a layer of air can be demonstrated between these structures and the lung.

We have used it only occasionally because, in most instances, we have felt that it was important to remove the tumor regardless of its exact site of origin and because pneumothorax is not necessary as a preliminary preoperative procedure.

Parenchymal Masses.—Shadows seen in the parenchyma of the lung, free from the lung root, make up the largest group of roentgenologic findings in the nonmalignant group. Diagrams of the x-ray findings are seen in Fig. 3, and although it is impossible to discuss all of these types in detail, certain examples will be presented. The differentiation between the x-ray findings in simple lung abscess and carcinoma is difficult. The onset of a pulmonary abscess is more abrupt, the symptoms more severe, and the roentgen shadow increases more rapidly. When the subacute stage is reached, after a few weeks, there is little change in the size of the x-ray shadow. In the early stage of development of a lung abscess, the zone of infiltration about the abscess is usually greater in the inflammatory cases than in the malignant ones, although exceptions to this rule may be seen (Fig. 7, Case M). As the abscess becomes chronic and fibrosis takes place, frequently only a solid mass is found on the x-ray, as shown in Case 4. This 61-year-old patient gave a history of three months' cough and expectoration with a low-grade fever. X-rays (Fig. 3) showed an enlarging, fairly homogenous mass with a fairly smooth border, in the left lower lobe. In contrast, Case B represents a 42-year-old man with a four-month history of cough and expectoration following tonsillectomy. On the chest x-ray of this patient (Fig. 7), an irregular shadow of the right middle lung field showed rarefaction suggestive of abscess cavities. In spite of the history of possible aspiration following tonsillectomy, a thoracotomy was performed and a bronchiogenic carcinoma removed.

Benign lung tumors generally present slower growing parenchymal masses with relatively smooth rounded contours, as compared with the malignant pulmonary neoplasms. In Case 22, a 50-year-old woman complained of cough and pain in the chest of twelve months' duration. The x-ray showed a lobulated shadow in the lower right lung field. An adenoma of the lung was proved at operation. Similar findings were noted in Case C. Here a 29-year-old man complained of cough for three years and repeated hemoptysis for two years. The roentgen finding was a circumscribed homogenous mass of the lower right lung field. With the three-year history and the youth of the patient, a benign tumor was anticipated; however, an adenocarcinoma was removed at operation. These cases are typical of the difficulty experienced in distinguishing between peripheral benign and malignant tumors from the roentgenologic picture.

Early pulmonary tuberculosis may show an enlarging shadow which, before cavitation occurs and tubercle bacilli are liberated into the bronchial tree, is indistinguishable from a peripheral cancer. In Case 8, an irregular shadow was present in the right upper lobe, in the pulmonary parenchyma, close to the mediastinum. Repeated cultures of sputum, including a specimen aspirated at bronchoscopy, were negative for tubercle bacilli. This patient, a 45-year-old woman, presented a history of cough, low-grade fever, and scanty sputum. She was not appreciably sick and refused to have this mass removed surgically. Some months later, when the lesion drained into the bronchus, she had high fever with

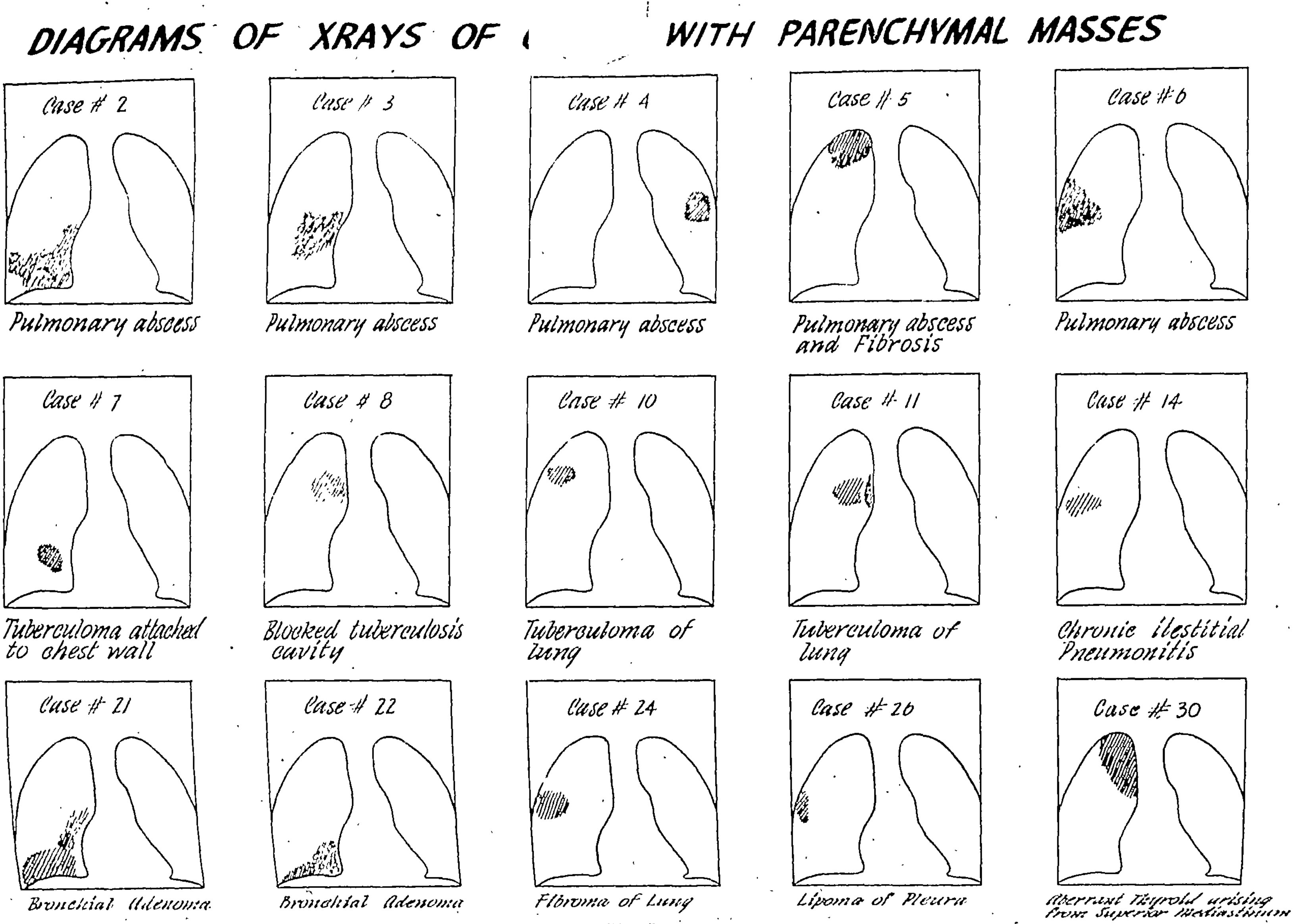

DIAGRAMS OF XRAYS OF WITH PARENCHYMAL MASSES
Case # 2
Pulmonary abscess
Case # 3
Pulmonary abscess
Case # 4
Pulmonary abscess
Case # 5
Pulmonary abscess and Fibrosis
Case # 6
Pulmonary abscess
Case # 7
Tuberculoma attached to chest wall
Case # 8
Blocked tuberculosis cavity
Case # 10
Tuberculoma of lung
Case # 11
Tuberculoma of lung
Case # 14
Chronic ilestitial Pneumonitis
Case # 21
Bronchial Adenoma
Case # 22
Bronchial Adenoma
Case # 24
Fibroma of Lung
Case # 26
Lipoma of Pleura
Case # 30
Aberrant Thyroid arising from Superior Mediastinum

FIG. 3.

profuse expectoration. At this time the sputum became positive for acid-fast bacilli and cavitation was seen on the x-ray. In Case D, a 53-year-old woman, there was six months' cough with ten pounds weight loss and negative sputum tests for acid-fast bacilli. A slightly irregular shadow was seen in the upper portion of the right upper lobe. This mass gradually increased in size over a period of several months. This patient consented to operation and a bronchiogenic carcinoma was removed.

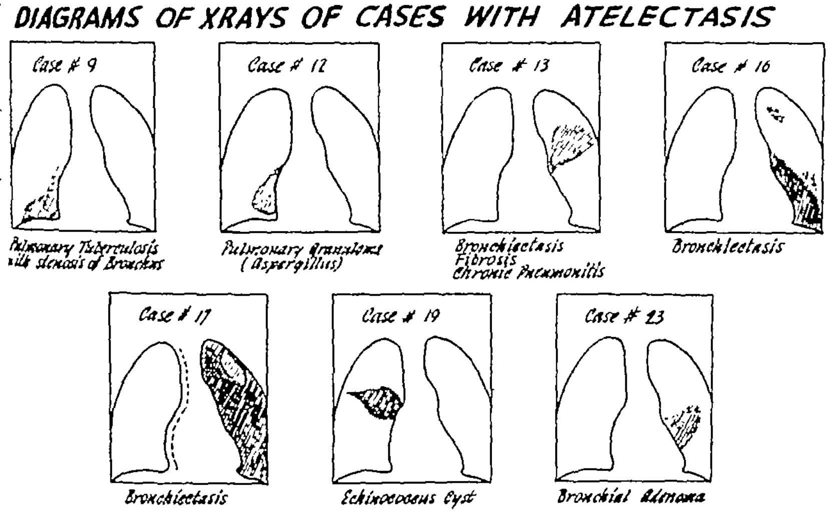

DIAGRAMS OF XRAYS OF CASES WITH ATELECTASIS
Case # 9
Pulmonary Tuberculosis with stenosis of Bronchus
Case # 12
Pulmonary Granuloma (Aspergillus)
Case # 13
Bronchiectasis Fibrosis Chronic Pneumonitis
Case # 16
Bronchiectasis
Case # 17
Bronchiectasis
Case # 19
Echinococcus Cyst
Case # 23
Bronchial Adenoma

Fig. 4.

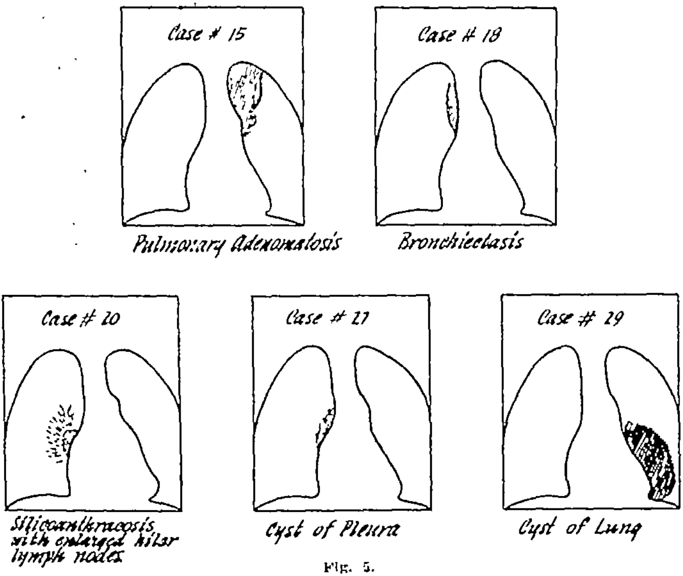
Atelectasis.—Atelectasis is an x-ray finding that is commonly associated with bronchial obstruction, resultant from an endobronchial tumor, inflammatory lesion, or foreign body. When this obstruction is present in the main-stem bronchi or the orifices of branch bronchi, the diagnosis is readily established by bronchoscopy. In upper lobe obstructions and occasional middle lobe obstructions it may not be possible to see the obstructing mass. Only rarely will a lower lobe obstructing mass be invisible to the bronchoscopist. A diagram of the x-ray findings is seen in Fig. 4. In the benign tumors atelectasis, if present, is usually lobar and a positive diagnosis can readily be made with the bronchoscope. If lobular atelectasis is present, as in Case 23, then the diagnosis rests on operative findings. In this case, a 24-year-old woman complained of recurrent hemoptysis and pneumonia over a period of three years. X-ray showed a shadow in the region of the lingula of the left upper lobe. Following a negative bronchoscopy, a bronchogram demonstrated an obstruction of the lingular bronchus. An adenoma was removed at operation. Case E (Fig. 7) was a 40-year-old man with a history of weakness, cough, and hemoptysis of nine months' duration. X-ray showed an irregular shadow in the left middle chest which, on lateral view, was seen to be a lobular atelectasis of the superior posterior branch bronchus of the left lower lobe. Following a course of antibacterial therapy, the shadow became markedly smaller; however, most of the symptomatology persisted and at surgical exploration a carcinoma of the lung was removed. Here are two cases of lobular atelectasis, one due to a benign tumor and one a malignant one. Only the longer history pointed to the benignity of the case of adenoma. However, we have seen a fair number of cases of bronchiogenic carcinoma where the history extended over a period of years, in one case as long as eight years.

Atelectasis due to inflammatory conditions presents a variety of findings (as with the benign tumors) and is most common in the upper and middle lobes. Case 19 illustrates a difficult diagnostic problem. This 52-year-old man had symptoms of cough for one year, hemoptysis, and pain in the right chest. The chest x-ray revealed a roughly triangular shadow that was interpreted as atelectasis of a lobule of the right upper lobe. The bronchoscopy was repeatedly negative. At surgical exploration an unusual shaped echinococcus cyst was removed. Since this diagnosis was not suspected preoperatively, no skin test for echinococcus had been done. Another film showing atelectasis of a lobule of the left upper lobe was present in Case 13, where the history was that of fever, cough, and expectoration of 3½ months' duration in a 53-year-old man. At operation, interstitial pneumonitis was found. These cases are contrasted with Case G. In this case a 55-year-old man complained of cough, fever, and expectoration of six months' duration. As was true in all these cases, the bronchoscopy in this case failed to show a bronchial block. A primary bronchiogenic squamous cell carcinoma was removed at surgery.

Central Masses.—The finding of a central mass in the chest x-ray in a patient with symptoms compatible with bronchiogenic carcinoma makes this diagnosis a likely possibility. In these cases the diagnosis of malignancy is confirmed most often at bronchoscopy. A diagram of the x-rays in the benign group is seen in Fig. 5. One of the benign patients, with a hilar mass on the x-ray and giving a history of cough and palpitation of ten months' duration, had a cyst of the pleura. In the hilar inflammatory lesions the x-ray findings were indistinguishable from carcinoma. Thus, Case 18, who proved to have bronchiectasis of an azygos lobe, presented an x-ray shadow similar to a proved case of carcinoma of the lung (Case H). In a like manner (Case 15) pulmonary adenomatosis may show a perihilar shadow which greatly resembles an adenocarcinoma (Case J).

Pulmonary Abscess.—We have previously discussed the lung abscesses that show a more or less solid mass on x-ray examination. The pulmonary abscess which persists and presents the roentgen finding of irregular areas of pulmonary infiltration and rarefaction also offers a difficult diagnostic problem (Fig. 6). There were only two patients in this series with these findings. The first, Case 1, a 70-year-old man, gave a history of five months' cough, sputum, and hemoptysis. The x-ray findings (Fig. 6) were very similar to Case K, in which adenocarcinoma was proved at operation. In the second, Case 25, this 49-year-old man

DIAGRAMS OF XRAYS OF CASES WITH CENTRAL MASSES



Pulmonary Adenomatosis

Bronchiectasis

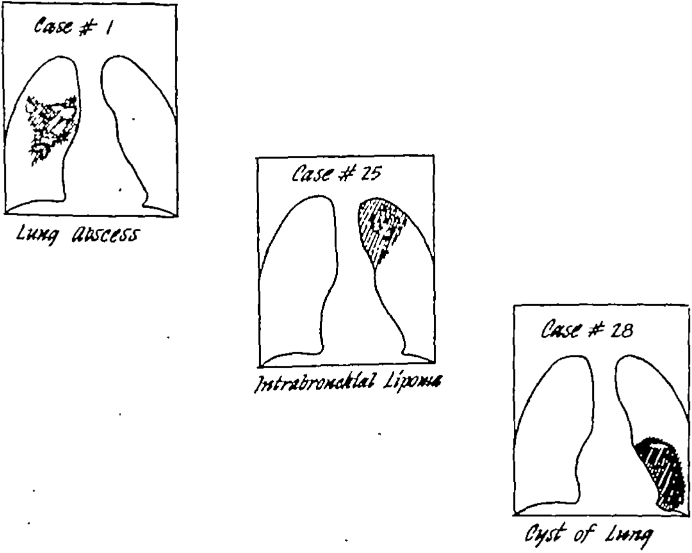
Silicoanthracosis with enlarged hilar lymph nodes

Cyst of Pleura

Cyst of Lung

Fig. 5.

DIAGRAMS OF XRAYS OF CASES WITH ABSCESSES & CYSTS



Lung abscess

Intrabronchial Lipoma

Cyst of Lung

abscess, did not show malignant cells. However, with failure of the abscess to heal, subsequent biopsies revealed the presence of a carcinoma. Had we treated this case with pulmonary resection instead of drainage of the abscess cavity when we first saw the patient, it is quite likely that it would have been possible to have removed the malignant tumor. With the improvement in surgical technique, the results of pulmonary resection for lung abscess have been very much better. A long period of drainage of the abscess is obviated and secondary measures to close the bronchial fistula are not necessary with lobectomy. Because of these facts and because at exploratory thoracotomy a lung cancer can be diagnosed and properly treated, we are coming to the point of view that pulmonary resection instead of surgical drainage is the procedure of choice for a lung abscess that does not promptly respond to conservative measures.

(2) Tuberculosis: Early pulmonary tuberculosis in persons of cancer age may occasionally present a clinical picture that is identical with bronchiogenic carcinoma. In the vast majority of instances, the differential diagnosis can be made with careful sputum examinations. The specimen of sputum obtained at bronchoscopy by aspirating the bronchus and draining the pulmonary lesion offers the best chance for detection of the tubercle bacilli. If the patient is expectorating appreciable quantities of sputum, then a negative examination usually rules out tuberculosis. Concentration of three-day pooled specimens of sputum and the more sensitive culture or guinea pig inoculations are the best tests for the detection of acid-fast bacilli. However, in an expanding peripheral pulmonary lesion it is frequently unwise to wait the six weeks for a negative culture for acid-fast bacilli or a guinea pig test when bronchiogenic carcinoma is a strong possibility. Also there is evidence to show that it is wise to resect so-called "tuberculomas" of the lung while the sputum is still negative and the lesion has not broken into the bronchus. In Case 8 of our series, had pulmonary resection been performed when we so advised, it seems likely that spread to the three other lobes of the lung and the necessity for an extensive thoracoplasty would have been prevented. In Case 7, in which the tuberculoma was attached to the chest wall and lung, the possibility of a tuberculous empyema was obviated by resection. In Case 9, in which atelectasis of the right middle lobe and an extensive hemoptysis were the predominating points in the clinical picture, more careful sputum studies would have probably revealed the diagnosis. These last cases are most unusual. The real problem exists in the tuberculoma arising at a distance from the pulmonary hilum, in which the sputum does not contain tubercle bacilli. Here perhaps a very strongly positive tuberculin test may offer presumptive evidence of tuberculosis. We believe that exploratory thoracotomy and resection of such lesions is justified as was done in the two cases in this series. Not only will a possibly early carcinoma of the lung be properly dealt with, but there is a great likelihood that the patient would be saved spread of the tuberculous process to other lobes of the lung should a tuberculoma be removed. Prolonged rest and the general regimen for tuberculous patients must be added to the postoperative care once a diagnosis of tuberculosis has been definitely established by examination of the resected specimen.

(3) Nonspecific granuloma: In the single case of nonspecific granuloma of the lung (Case 12), the pathologic findings were that of a chronic infectious

granuloma that did not resemble tuberculosis. The etiology of this lesion has not definitely been determined although Aspergillus was cultured from the sputum; however, the microscopic sections of the specimen were not typical of fungus infection. Because there is no diagnostic test that can be performed before surgery, these cases cannot be distinguished from early pulmonary malignancy. Since the true character of the lesion can be determined only by microscopic section, early removal seems to be indicated. The patient in this series was apparently cured by the resection; there has been no recurrence of the condition.

(4) Chronic pneumonitis (interstitial): This classification is somewhat unsatisfactory as it contains a variety of lesions in the alveoli and interstitial tissue producing pathologic changes. The clinical picture is one of localized pulmonary infiltration similar to that of an acute pneumonitis that becomes chronic or gradually spreads in spite of intensive sulfonamide or penicillin therapy. One might suspect that virus pneumonia might come into this category. The x-ray shadows of virus pneumonia, although not typical in themselves, do tend to come and go, and move around. In those cases in which the process lasts for several months, there usually has been enough variation in the x-ray findings to show that the lesion is inflammatory and not neoplastic. The etiology in the three examples of chronic interstitial pneumonitis in this series was different in each case. In Case 14, the pneumonitis was associated with a pneumolith; in Case 15, the infection from sheep gave the picture of pulmonary adenomatosis; and in Case 13, no definite etiology of the interstitial pneumonitis was determined. It should be emphasized that these are not cases of so-called "unresolved pneumonia," a condition that is usually a misnomer and represents some other pathologic condition. In these cases, interstitial or interalveolar inflammations resulting in fibrosis of the lung account for the persistence of the symptomatology and the shadows seen in the x-ray picture. These conditions are rare, and no criterion for diagnosis and treatment has been established. Surgical exploration and resection seem indicated when the persistent x-ray shadow resembles that of bronchiogenic carcinoma.

(5) Bronchiectasis: Bronchiectasis is a disease that is chronic in character with well-known signs and symptoms that make the diagnosis usually clear-cut. It occurs most frequently in the first three decades of life and because of its history of chronic pulmonary suppuration, repeated pneumonitis, or hemoptysis, is rarely confused with pulmonary tumor. The x-ray usually shows some peribronchial infiltration and Lipiodol injection establishes the diagnosis of bronchiectasis.

In over 200 patients with bronchiectasis, there were only three in which we suspected a pulmonary malignancy. All three of these showed atelectasis. In two patients there was atelectasis of the left lower lobe, and at bronchoscopy a bleeding obstructing lesion of the lower bronchus was seen. Because atypical cells which resembled malignant cells were seen on the microscopic section of the biopsy specimen, bronchiogenic carcinoma was the tentative preoperative diagnosis. At operation, the lesions were proved to be nonmalignant. In the third case, since the bronchoscopy was negative, an enlarging perimediastinal shadow of the accessory azygos lobe was indistinguishable from a perihilar bronchiogenic carcinoma. Except when an anomalous lobe or possibly an upper lobe lesion is present, or the biopsy specimen of granulation tissue in the bronchus is equivocal, bronchiectasis will not be confused with bronchogenic carcinoma. In any event, the treatment of bronchiectasis is pulmonary resection provided that the vital capacity or disease in the contralateral lung, etc., does not contraindicate surgery.

(6) Echinococcus: Echinococcus disease of the lung usually presents fairly typical clinical pictures. There is often a history of exposure to animals, the x-ray shows one or more cysts in the lung, and similar cysts of the liver are not uncommon. The skin and precipitation tests are highly sensitive and can be relied upon, if strongly positive, to confirm the diagnosis. In the one case in this series (Case 19), the chest x-ray was that of a more or less triangular density close to the hilum. Because this lesion did not resemble a cyst, we did not consider echinococcus as a possibility and so did not perform the diagnostic tests for this disease. A pulmonary malignancy seemed the most likely diagnosis. We have seen other cases in which echinococcus cyst was the suspected diagnosis but in whom the skin test was negative. Exploration revealed pulmonary malignancy. Since the best treatment for echinococcus disease is pulmonary resection, if the condition of the patient permits, pulmonary resection is the procedure of choice.

(7) Silicosis: Silicosis is an occupational disease resulting from a long exposure to soluble silicate dust. The history of chronic cough and dyspnea following the inhalation of silica dust usually may be obtained. The chest roentgenogram shows a hilar, sunburst type of infiltration which is usually bilateral. Often there is a fine-grained miliary infiltration in the middle lung fields, leaving the apices and the costophrenic angles clear. Rarely will this clinical and x-ray picture be confused with bronchiogenic carcinoma. In our case there was a history of recent hemoptysis the day before in a man who had previously considered himself well. The x-ray showed a rounded hilar mass on the right and bronchoscopy showed infiltration and distortion of the intermediate bronchus which was interpreted as invasion of the tumor. He had a rather straight left heart border which, in the absence of rheumatic heart disease, we could not explain. An exploratory thoracotomy seemed justified to rule out a bronchiogenic carcinoma. The finding of extensive silicosis of the mediastinal lymph nodes and lung at operation revealed the true source of the hemoptysis.

II. Benign Tumors.—Benign pulmonary tumors occur with one-tenth the frequency of bronchiogenic carcinoma. They grow slowly and usually present the symptoms of bronchial obstruction or hemorrhage over a long period of time. Since most of these benign neoplasms arise in the main bronchus or orifices of the branch bronchi to the various lobes, their diagnosis may be made with certainty by bronchoscopy and biopsy in the majority of instances. Some difficulty arises in interpreting the microscopic picture of the varied cell types found in adenomas, but with repeated biopsies the experienced pathologist can usually rule out carcinoma.

Although more common in the younger age groups, these benign tumors are seen in middle-aged persons, also. When the neoplasm arises beyond the range of bronchoscopic vision, the diagnosis is most difficult.

All of the five cases of benign pulmonary tumor in this series arose in bronchi beyond bronchoscopic vision. Three of these cases were adenomas of the bronchus. This represents three out of fourteen cases of adenoma that we have treated in which bronchoscopy failed to show the nature of the tumor. In the other eleven, the diagnosis was proved by bronchoscopy. Two other benign pulmonary tumors in this series were extremely rare: (1) a lipoma of the bronchus arising in the left upper lobe; and (2) a fibroma arising in the right upper lobe. The sixth case proved to be also a rare lesion, a lipoma of the pleura which presented a peripheral shadow simulating bronchiogenic carcinoma. Resection of the peripheral benign tumors was indicated, as cancer could not be ruled out with certainty. Most adenomas of the bronchus come to surgery eventually because of infection in the lung or hemorrhage. These tumors are all potentially malignant so excision is the treatment of choice.

III. Developmental Conditions.—

(1) Pulmonary cysts: Solitary pulmonary cysts occurring in persons of cancerous age may simulate bronchiogenic carcinoma. If the cysts are multiple, then the diagnosis of carcinoma is remote. The symptoms are varied and depend upon infection in the cyst, the bronchial communication, and the size and position of the lesion. If the pulmonary cyst is asymptomatic and found on routine examination of the chest, then it is unlikely that a malignant neoplasm is present. If, however, the symptoms of cough, and expectoration or hemoptysis are present, then the diagnosis of bronchiogenic carcinoma must be entertained.

In a series of eighteen cases of cystic disease that we have treated, three presented a clinical picture that led us to suspect bronchiogenic carcinoma. In each of these infection was present in the cyst and a communication existed between the cyst cavity and the bronchial tree. In two cases (Case 28 and 29), the cyst mass was in the distal portion of the lung fields and in one case it was contiguous with the hilum. The time element is important, for the longer the history, the less likely it is that a cancer is present. However, we treated one patient (Case M) with a cystlike lesion of the lung which proved to be cancerous, in which the symptoms had been present for 1½ years and a cystlike structure had been observed in chest x-rays over this period of time. Since the ideal treatment of symptomatic solitary pulmonary cyst is resection, then there is no harm in advising early surgery when bronchiogenic carcinoma cannot be ruled out.

(2) Intrathoracic goiter: Only rarely will the clinical picture seen with an intrathoracic thyroid resemble that of a primary pulmonary malignancy. Usually there is some associated enlargement of the cervical thyroid, and the intrathoracic goiter is attached to the parent structure. The symptoms of hyperthyroidism may be present. On fluoroscopy, the intrathoracic thyroid, being attached to the ribbon muscles of the neck, may be seen to rise on swallowing. The mass has smoother outlines in the x-ray than does a carcinoma, and symptoms, if present, are usually those of tracheal obstruction. In the malignant tumors of the lung located in the superior sulcus, pain in the shoulder, and Horner's syndrome with recurrent laryngeal nerve paralysis are present when the tumor mass casts a shadow on the x-ray as large as the one in the case we have presented (Case 30). If bronchiogenic carcinoma cannot be ruled out, then

an exploratory thoracotomy by opening the chest widely, not an operation through the suprasternal notch, should be employed, so that the lung may be removed if necessary.

PROGNOSIS

In twenty-five out of thirty nonmalignant cases in this series, healing of the pathologic condition could not be expected by conservative means alone (Table IV). The lung abscesses which had not responded to antibacterial treatment and bronchoscopic drainage definitely needed surgical treatment. The patients with bronchiectasis, ecchinococcus disease and persistent tuberculomas do not tend to heal spontaneously. In a like manner, benign tumors and the developmental condition could be cured only by resection. It must be admitted, however, that the asymptomatic lesions in the latter category might have existed for a long time before causing trouble. Yet their resection obviated possible difficulties from enlargement, infection, or malignant change. This leaves only the four cases with pulmonary granulomas and chronic pneumonitis in a borderline classification. Although the prognosis for these conditions is not well known without pulmonary resection, a state of chronic disease could be expected. In silicosis, no satisfactory treatment has been devised once the process becomes advanced.

RESULTS

The results of surgery in these thirty nonmalignant cases are shown in Table IV. The most important fact to be learned from this chart is that in twenty-seven out of thirty cases a cure was effected by the surgical treatment. These patients have remained well for a period of from four months to six years since surgery. In twenty-five instances, or five-sixths of the cases, resection of the lesion was performed. In one of the five remaining cases, pneumonolysis performed at exploration effected adequate drainage of a lung abscess and subsequent healing of the lesion. In the other patient, a thoracoplasty resulted in ultimate curing of the pulmonary tuberculosis. There were two patients unimproved by operation. In one with severe hemoptysis, the resection of the pulmonary tissue failed to arrest the latent tuberculosis in the opposite lung. In

TABLE IV. RESULTS IN THIRTY BENIGN CASES

DIAGNOSIS	CASES	OPERATION	CURED	UNIMPROVED	DIED	PROGNOSIS WITHOUT SURGERY
Inflammatory						
1. Lung abscess	6	Resection, 5 Exploration and lysis, 1	6	0	0	Poor
2. Tuberculosis	6	Resection, 5 Thoracoplasty, 1	5	1	0	Poor
3. Pneumonitis	3	Resection, 3	2	0	1	Fair
4. Bronchiectasis	3	Resection, 3	3	0	0	Poor
5. Granuloma		Resection	1	0	0	Fair
6. Echinococcus	1	Resection	1	0	0	Fair
7. Silicosis	1	Exploration	0	1	0	No treatment
Benign Tumors						
1. Adenoma	3	Resection	3			Poor
2. Lipoma	2	Resection	2			Poor
3. Fibroma	1	Resection	1			Poor
Developmental						
1. Cysts	3	Resection	3			Poor
2. Thyroid	1	Resection	1			Fair
Totals	30		27	2	1	

the other unimproved patient, in whom silicotic lymph nodes were found, only an exploratory thoracotomy was performed. The one operative fatality in this group occurred in a man 55 years old with chronic pneumonitis. The cause of death was an extensive spread of infection to the opposite lung, uremia, and sepsis. In reviewing this case, we cannot find any diagnostic signs or symptoms by which bronchiogenic carcinoma could have been ruled out prior to surgery.

DISCUSSION

In this group of conditions simulating bronchiogenic carcinoma which has been presented, no hard and fast rule can be given to eliminate malignancy. Even after this intensive study, should we encounter similar cases in the future we will operate upon them, for, in the vast majority, carcinoma cannot be excluded.

In these lesions beyond the range of bronchoscopic visibility, the elimination of the possibility of open pulmonary tuberculosis is the most important clinical differentiation. The fact that a shadow on the x-ray film appears to be quiescent in no way excluded bronchiogenic carcinoma. Even if temporary decrease in the size of the x-ray shadow takes place with antibacteric therapy, the lesion may still be malignant; but, if the lesion is migratory from lobe to lobe, an inflammatory lesion can be expected.

Yet, if exploratory thoracotomy is to be performed for these patients, should a pneumonectomy with its higher attendant risks be performed in every instance? The problem confronting the surgeon who has the chest open and the pathologic process under visual and manual examination is often most difficult. Unless the diagnosis of carcinoma is obvious, it is wise to perform a biopsy or wedge resection of the lung which includes the lesion, if possible. Immediate frozen sections and microscopic examinations should be carried out. If a carcinoma is proved, then a pneumonectomy should be performed providing the patient's condition makes this feasible. If the lesion is nonmalignant, then local resection or lobectomy is the procedure of choice. We believe that the evolution of the management of a suspected case of peripheral bronchiogenic carcinoma has reached the same status that is now current usage for carcinoma of the breast. When a lump is felt in the breast, biopsy or local excision is performed. If carcinoma is proved by microscopic examination, a radical mastectomy is performed. Thus, in suspected peripheral bronchiogenic carcinoma, exploratory thoracotomy and biopsy or local excision is performed. Only if cancer is proved is a total pneumonectomy necessary.

CONCLUSIONS

1. Thirty operated cases of nonmalignant intrathoracic lesions simulating peripheral bronchiogenic carcinoma have been reviewed. This group consisted of twenty inflammatory conditions, six benign tumors, and four developmental abnormalities.

2. The difficulty of the clinical problem in the early diagnosis of bronchiogenic carcinoma is emphasized by the fact that in only approximately one-half of the cases of carcinoma out of a series of 300 that we have treated, could the carcinoma be diagnosed by bronchoscopy. All lesions beyond the limits of bronchioscopic diagnosis are classed as peripheral.

TABLE V. CLINICAL DATA OF THIRT[illegible] CONDITIONS SIMULATING BRONCHIOGENIC CARCINOMA

CASE NO.	AGE, SEX	X-RAY	SYMPTOMS	OPERATION	DIAGNOSIS	RESULT
			Inflammation: (1) Abscess			
1. F. N.	70 M	Lung abscess	5 months cough, sputum hemoptysis, dyspnea; 15 lb. weight loss	Right pneumonectomy	Bronchiectasis and abscess	Cured
2. K. M.	65 M	Parenchymal mass	3 months cough, sputum, hemoptysis, wheeze, dyspnea, pleuritic pain	Exploration and pneumonolysis	Pulmonary abscess	Cured
3. E. K.	37 M	Parenchymal mass	3 months cough, sputum, pain	Right lower lobectomy	Pulmonary abscess	Cured
4. R. S.	61 M	Parenchymal mass	3 months cough and pain following an operation for herniotomy	Left pneumonectomy	Pulmonary abscess	Cured
5. M. H.	49 F	Parenchymal mass	1 month sputum, wheeze, hemoptysis, and high fever	Right upper lobectomy with partial excision of chest wall and ribs	Pulmonary abscess and fibrosis	Cured
6. N. C.	58 F	Parenchymal mass	1 month cough, sputum, fever, dyspnea and weakness	Right pneumonectomy	Pulmonary abscess	Cured
			(2) Tuberculosis			
7. L. S.	34 F	Parenchymal mass	7 months' cough, sputum, low fever, 15 lb. weight loss	Excision of node	Tuberculoma attached to chest wall	Cured
8. S. P.	45 F	Parenchymal mass	3 weeks, cough, sputum, fever	(Refused exploration) Right thoracoplasty	Blocked tuberculous cavity	Cured
9. P. B.	59 M	Atelectasis of right middle lobe	12 months cough, sputum, hemoptysis, fever and dyspnea	Right pneumonectomy	Pulmonary tuberculosis with stenosis of bronchus	Unimproved
10. L. W.	37 M	Parenchymal mass	No symptoms	Right partial lobectomy	Tuberculoma of lung	Cured
11. O. C.	54 F	Parenchymal mass	(Gastrointestinal symptoms for 5 months)	Right lower lobectomy	Tuberculoma of lung	Cured
			(3) Granuloma			
12. L. K.	39 M	Atelectasis of right middle lobe	12 months cough, sputum, wheeze, and hemoptysis	Right middle lobectomy	Pulmonary granuloma (Aspergillus)	Cured
			(4) Pneumonitis			
13. F. N.	53 M	Abscess and atelectasis	4 months cough, sputum, pain	Left pneumonectomy	Bronchiectasis and fibrosis, and chronic pneumonitis	Died—(pneumonia) *Uremia*
14. H. W.	29 M	Lung abscess	4 months cough, pain, occasional small hemoptysis	Right middle and lower lobectomy	Chronic interstitial pneumonitis (Pneumolith)	Cured
15. H. B.	31 F	Parenchymal mass	8 months sputum, chills, fever, pleurisy: hemoptysis once	Left pneumonectomy	Chronic interstitial pneumonitis with fetalization (Adenomatosis)	Cured

(5) Bronchiectasis							
16. I. D.	29	F	Basal atelectasis	10 years sputum, cough, hemoptysis, dyspnea	Left pneumonectomy	Bronchiectasis	Cured
17. H. H.	49	F	Basal atelectasis	5 months cough, wheeze, dyspnea	Left lower lobectomy	Bronchiectasis	Cured
18. M. T.	42	F	Parenchymal mass	11 years ago bronchial polyp removed; yearly attacks of cough, wheeze, fever	Left upper lobectomy with azygos lobe	Bronchiectasis in azygos lobe of lung	Cured
(6) Echinococcus							
19. E. S.	59	F	Parenchymal mass	12 months cough, sputum, hemoptysis	Right exploratory thoracotomy with excision of cyst	Echinococcus cyst of lung	Cured
(7) Silicosis							
20. T. T.	59	M	Hilar mass	1 day hemoptysis, slight dyspnea	Right exploratory thoracotomy	Silicoanthracosis with enlarged hilar lymph nodes	Unimproved
Benign Tumors: (1) Adenoma							
21. I. W.	50	F	Parenchymal mass	5 months cough, sputum, hemoptysis, weakness	Right lower and middle lobectomy	Bronchial adenoma	Cured
22. F. R.	50	F	Parenchymal mass	12 months cough, pain, soreness	Right lower lobectomy	Bronchial adenoma	Cured
23. E. P.	33	F	Atelectasis and pneumonitis	48 months, recurrent bouts fever, cough, hemoptysis	Right upper lobectomy	Bronchial adenoma	Cured
(2) Fibroma							
24. M. M.	30	F	Parenchymal mass	24 months pain and cough	Exploratory thoracotomy with excision of tumor	Fibroma of lung	Cured
(3) Lipomas							
A. Bronchial							
25. M. B.	49	M	Lung abscess	18 months cough, wheeze, and pain	Left pneumonectomy	Intrabronchial lipoma	Cured
B. Pleural							
26. M. Mo.	60	M	Parenchymal mass	1½ months cough and sputum	Exploratory thoracotomy with excision of tumor	Lipoma of pleura	Cured
Developmental: (1) Cysts							
27. R. R.	55	M	Hilar mass	10 months cough and irregular heart action	Exploratory thoracotomy with excision of cyst	Cyst of pleura	Cured
28. M. U.	68	M	Parenchymal mass	5 months cough, sputum, hemoptysis, pain, and dyspnea	Right lower lobectomy	Cyst of lung	Cured
29. S. A.	40	F	Parenchymal mass	No symptoms	Exploratory thoracotomy with excision of cyst	Cyst of lung	Cured
(2) Aberrant Thyroid							
30. R. D.	29	M	Parenchymal mass	No symptoms	Exploratory thoracotomy with excision of tumor	Aberrant thyroid arising from the superior mediastinum	Cured

TABLE VI. REPRESENTATIVE CASES OF PROVED BRONCHIOGENIC CARCINOMA WITH NEGATIVE BRONCHOSCOPY

CASE	AGE SEX	X-RAY	SYMPTOMS	OPERATION	DIAGNOSIS	RESULT
A. H. S.	47 M	Large lung abscess with fluid level	1½ months cough, fever, hemoptysis	External drainage of abscess, with biopsy	Carcinoma, undifferentiated	Living at 6 months
B. F. S.	42 M	Parenchymatous mass near hilum	4 months cough, hemoptysis, following a tonsilectomy	Right pneumonectomy	Carcinoma, squamous IV	Died of metastases in 6 months
C. L. K.	29 M	Parenchymatous mass in lower lobe	Chronic cough for three years; hemoptysis two years before; hemoptysis recently	Right pneumonectomy	Adenocarcinoma	Living and well at one year
D. L. H.	53 F	Parenchymatous mass in upper lobe	6 months cough; 10 lb. loss in weight	Right pneumonectomy	Carcinoma undifferentiated	Living and well at one year
E. B. B.	40 M	Small area of atelectasis in dorsal branch of lower lobe	9 months weakness, cough, hemoptysis	Left pneumonectomy	Carcinoma, squamous II	Died of metastases in one year
F. A. S.	65 M	Large parenchymatous mass near left hilum	Dyspnea for 20 years; hemoptysis eight years before; recent small hemoptysis	Left pneumonectomy	Carcinoma, squamous cell	Living and well at 9 months
G. F. T.	61 M	Atelectasis at left apex	44 lb. weight loss following extraction of teeth; one month of cough	Left pneumonectomy	Carcinoma, squamous cell	Died third postoperative day
H. J. A.	44 F	Parenchymatous mass	12 months cough and sputum	Right pneumonectomy	Adenocarcinoma	Died of metastases in one year
J. H. C.	63 M	Parenchymatous mass near hilum	12 months cough, sputum, hemoptysis, and occasional fever	Left pneumonectomy	Carcinoma, squamous cell	Living 2 years later but has metastases
K. M. L.	55 F	Atelectasis in upper lobe	12 months cough; 20 lb. loss weight; 4 months pain in left chest	Lobectomy, left upper lobe	Papillary adenocarcinoma	Living and well at 1 year
L. M. S.	45 M	Lung abscess	4 months cough, wheeze, pain, hemoptysis	Exploratory thoracotomy	Squamous cell carcinoma	Living at 6 months
M. L. P.	55 M	Infected lung cyst	18 months cough and sputum	Lobectomy, left lower lobe	Papillary cyst adenocarcinoma	Living and well at 4 months

3. After a careful study of the clinical and x-ray findings, we are forced to admit that most often the differentiations between the peripheral malignancies and nonmalignant conditions cannot be made without exploratory thoracotomy.

4. Exploratory thoracotomy and microscopic examination of biopsied specimens represent the only sure methods of distinguishing between the malignant and this group of nonmalignant peripheral lesions.

5. In twenty-three out of thirty cases in this benign group simulating bronchiogenic carcinoma, cure could not be expected by conservative treatment; six cases fell in a borderline group; and one was hopeless regardless of treatment employed.

6. Twenty-seven out of the thirty nonmalignant conditions were cured by surgery, two were unimproved; one postoperative death occurred.

7. This study should give confidence to the surgeon to perform exploratory thoracotomy for the peripheral intrathoracic lesions where bronchiogenic carcinoma cannot be ruled out. If a carcinoma is found, total pulmonary resection offers the only chance for cure. If a nonmalignant condition is discovered, we can conclude from this experience that in most instances the pathologic condition will prove to be one that is cured by simple local resection.

8. We believe that the management of a suspected case of peripheral bronchiogenic carcinoma has reached a status similar to that of suspected carcinoma of the breast with exploration, biopsy, and radical excision, if cancer is proved.

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DISCUSSION

DR. EVARTS A. GRAHAM, St. Louis, Mo.—I want to commend Dr. Brewer for bringing this to our attention so forcibly.

I agree wholeheartedly that exploratory thoracotomy should be undertaken much more often than it is. The reason that it is not undertaken more often is simply because of the conservatism of members of the medical group, who generally have these patients in their control over a long period of time.

Dr. Brewer did not say anything in particular about tuberculoma, but it seems to me that with the present safe state of thoracic surgery one will not go far wrong in advocating the removal of large tuberculomas. We have been carrying out this policy for some time with no regrets.

On the other hand, I am sure we are familiar with patients who have carried tuberculomas for an indefinite period of time, and were told there was nothing to worry about, only to have the thing suddenly become active, with the dissemination of tuberculosis, often in a bilateral form, with the serious consequences of that complication.

DR. DAVID H. WATERMAN, Knoxville, Tenn.—I agree entirely with Dr. Brewer that tuberculosis should, of course, be ruled out in these patients. I would like to bring to your attention, however, eight cases we have had in which a positive sputum was obtained which in each case proved to be a red herring.

In all of the eight cases a diagnosis of bronchiogenic carcinoma proved to be the main pathology, but in three of them the presence of positive sputum delayed our surgery sufficiently long that a poor result was obtained where a good result might have been achieved by earlier operation.

The explanation for the positive sputum may be that the bronchiogenic carcinoma has eroded into an old tuberculous focus. I have heard other chest surgeons make the same observation. To reiterate, I think we cannot place too much importance on a positive sputum, particularly if it is an isolated specimen.

DR. F. R. MAUTZ, Cleveland, Ohio.—I just wish to show one case that has been quite interesting and instructive to me.

(Slide.) This was a man 36 years old, who, a year or so previously, had a rather severe injury to the left chest and some months later began to have pains in the left chest. A month before this picture was taken, he consulted his physician, and this circumscribed lesion was found in the periphery of the left lung field.

Bronchoscopy did not help us make a diagnosis. He had no fever or signs of a pyogenic inflammatory lesion, so we proceeded with an exploratory thoracotomy, on the assumption that we were dealing with a primary lung tumor.

At operation we did find a lesion in the periphery that came up near the surface of the pleura. Apparently it went across the interlobar fissure, and we were still a bit at a loss to know what it was. It was rather hard in consistency. We thought that perhaps we could get some help from a frozen section and we took a small piece from the pleura and had a frozen section done in the operating room which gave us the impression that we were dealing with an adenocarcinoma, so we proceeded with a pneumonectomy.

(Slide.) This was the lesion as it appeared in the lung; when the pathologist examined the paraffine sections of the lesion, he called me up and asked me if I would check to see what the man's Wassermann reaction was. I went to the chart, and to my chagrin, found that a routine admission Wassermann had not been done. There was one listed as having been drawn the day of operation, and needless to say, it was 4 plus.

This patient has been followed for three years and he has remained well. A course of antisyphilitic therapy has been recommended but the patient has not been very faithful about taking the treatments. No doubt the penicillin that he had following operation was helpful in this regard.

Does the essayist have any comments to make on the treatment of these large gummas of the lung? If we had known that this was a gumma, we would have instituted some antisyphilitic therapy prior to thoracotomy.

DR. EDGAR W. DAVIS, Washington, D. C.—I believe for scientific reasons—and to emphasize what Dr. Graham has said—that if one's clinical diagnosis could be substantiated preoperatively it possibly would influence the clinicians to refer these undiagnosed lesions to the surgeons. However, for practical purposes I do not feel that it is necessary to ascertain the clinical significance preoperatively of these lesions. In my opinion all of them should be explored.

In 1945 we* reported fifty-eight cases that had had all conceivable studies in our armamentarium. We were unable to arrive at any definite diagnosis in any case. We operated on these patients and in the over-all age group we found 73 per cent to be malignant.

We have just been reviewing a series of intrapulmonary tumors. We have forty in this series. One patient refused surgery and thirty-nine were operated upon. This group ranges anywhere from 29 to 69 years of age, with an average age of about 52 years. Of this group of forty cases, we have a total of 70 per cent malignancies. Of the forty patients, there were twelve who had no symptoms at all. These twelve were picked up largely during the war, when inductees or volunteers for service in the armed forces were routinely screened. They had no symptoms at all, and were surprised to be told that they had anything in their chest which would disqualify them for service in the armed forces. Of these patients without symptoms, 66 per cent, or 8, had malignant tumors.

I am sure all of us were very interested in these x-rays presented by Dr. Brewer. He called some of them carcinoma that I did not think were carcinoma. This last case presented looked to me as if it were a very clean-cut film of a cyst in the lung. This shows the necessity for operating upon what roentgenographically appears to be an innocuous lung cyst. Dr. Graham has called our attention a number of times in recent years to the fact that many of these cysts have malignancies within them.

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*Drs. Edgar W. Davis and Roy G. Klepser, Washington, D. C.

I sincerely believe that so far as the practical application of therapy in these undiagnosed, intrapulmonary, or intrathoracic neoplasms is concerned, that it is just as imperative to operate and find out their true significance as it is to remove an undiagnosed nodule from the breast.

DR. RICHARD H. SWEET, Boston, Mass.—I have long been an advocate of this procedure in these doubtful cases where diagnosis is so difficult, but I would also like to point out to you that, at least in my experience, it is not such an easy matter with the lung under our fingers and with our eyes upon it, to be absolutely sure of what we are dealing with.

I have made errors in both directions—calling benign lesions malignant ones, and malignant ones benign. On the other hand, I think we can make wide use of this method, many times performing a biopsy, actually taking pieces of lung tissue, lymph nodes, and so forth, in order to find out exactly what we are dealing with, but even then we have to wait sometimes for several weeks for the pathologist to make up his mind as to what it was that we took out for him.

There is one interesting group of cases which I have encountered that I think Dr. Brewer mentioned on his list of diagnoses, which we have called chronic pneumonitis, and which appears to be a clinical and pathologic entity, and which, in our hands, is very difficult to differentiate from carcinoma, even at the operating table. Perhaps you would like to comment on your experience with that, Dr. Brewer.

DR. A. LINCOLN BROWN, San Francisco, Calif.—There is one form of chronic pneumonitis which I am sure the essayist would not object to having added to the list; that is lipoid pneumonia, of which one does not see too much. I have just had the experience again, in a fifth case. It is always very satisfactory to run across, and gives you a much better prognosis as far as the patient is concerned, but, being a progressive disease, warrants at least a local excision and possibly a lobectomy.

DR. L. A. BREWER, Los Angeles, Calif.—In response to the question regarding the gumma, I believe there are only a very few published case histories, so that this case, by all means, should be reported. We have not run across one in our series.

The problem that confronts the surgeon when he has the thorax open and can palpate the mass in the lung is often extremely difficult. Wherever possible, we take a biopsy of the lesion and the adjacent lymph nodes. Carcinoma can usually be ruled out in all cases except tumors covered by the great vessels close to the hilum.

As time goes on there will be more and more explorations, more local resections, and fewer pneumonectomies for all except the hilar masses. Actually, we did nine pneumonectomies, eleven lobectomies and eight local excisions in this series. As our experience widens, we will be able to tell more accurately which cases will need a total pneumonectomy.

I am sorry that this vast subject had to be covered in such a short period of time. There were many questions of interest that we would have liked to discuss further, such as tuberculosis, mentioned by Dr. Graham, interstitial pneumonitis, suggested by Dr. Sweet, and others. The written account of this paper presents more detail on these subjects.

We have presented this series of cases in the hope of stimulating surgeons in the Society to present their experiences with nonmalignant lesions simulating bronchiogenic carcinoma, for it is only by the collective experience of a large number of cases that the best standards of therapy can be evolved.

AN IMPROVED METHOD OF RESECTION OF PULMONARY SEGMENTS

REPORT OF A TECHNIQUE APPLIED IN SEVENTY OPERATIONS

RICHARD H. OVERHOLT, M.D. (BY INVITATION), FRANCIS M. WOODS, M.D.,
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PULMONARY diseases amenable to surgical excision often involve one or more segments of lobes. At times the affected segments are contiguous, but often they are distributed in different lobes either on one or both sides of the thoracic cavity. In such cases it is desirable to save the normal segments as functioning units. Where multiple areas are concerned, it may become imperative to conserve all healthy segments in order to preserve sufficient pulmonary function to sustain active life and yet eradicate the disease.

Thoracic surgeons have long recognized the surgical significance of the pulmonary segment. Nelson[6] discussed the segments from the standpoint of proper posturing of patients when bronchial drainage was necessary. He also pointed out that the superior segments of the lower lobes were entitled to be given separate consideration for they acted independently from an anatomic and clinical point of view. Churchill and Belsey[3] were early to point out the frequency of involvement of the lingula of the left upper lobe in bronchiectasis and the importance of its resection. They described a method of removing the lingula by preliminary occlusion of the segmental bronchus, reinflation of the lobe, and the division of lung tissue between clamps, and stated that "clamps are placed just on the atelectatic side to allow greater freedom in suturing. Running stitch ligatures are then placed on the lung substance held by the clamps." Churchill and Belsey also employed this method in two cases of bronchiectasis in which the basal group of segments were removed, thereby preserving the superior segment. Adams[1] has called attention to the practical importance of "segmental pneumonectomy" and has illustrated a method for removal of basal segments applying two clamps to the lobe. He places the blades of the clamps so that they grasp the lung from opposite directions and their points closely approximate one another so that all of the tissue between the superior segment and the basal group is included. Suturing of the lung surface is also recommended. Blades[2] has discussed the importance of the conservation of uninvolved segments, particularly in treating bilateral bronchiectasis. For the lingula, Blades has found the method of Churchill and Belsey entirely satisfactory. For removal of the superior segment of the lower lobe, the bronchus is occluded and clamps are applied to the line of demarcation. Blades states, however, that "partial excision of the basal division of a lower

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lobe necessitates incisions through rather thick vascular lung tissue. Extirpation of the diseased lobules in this location may be accomplished by placing one small hemostat at the desired position and incising the tissue below the level of the instrument. . . . After the division of approximately one inch of lung tissue the line of incision is approximated and the positions of the vessels held by the proximal clamp are determined. The vessels are controlled by suture ligatures before the clamp is removed. By repeating this maneuver, the segment or desired amount of lung tissue is excised. . . . The raw cut surface of the lung parenchyma is then covered with a large graft of parietal pleura which is obtained from the chest wall.'' Blades has employed this method in seven cases, not including lingulectomy.

For many years we used the methods described by Churchill and Belsey,[3] Adams,[1] and by Blades[2] for the excision of the lingula. This segment is the most accessible of all for it is the counterpart of a lobe (the right middle) and frequently is partially separated by an accessory fissure. It has but one intersegmental plane which is often a narrow one. The clamp and suture methods have not proved to be satisfactory in the excision of other segments. Lung clamps and hemostats cannot be placed precisely on the intersegmental plane. At some area in the intersegmental plane either too much or too little tissue will be included in the clamps. If the former, infected tissue may remain behind; if the latter, healthy tissue is traumatized. The use of clamps makes suturing obligatory. The raw surface of the adjacent and healthy segment cannot be sutured without distortion of its shape or reduction of its volume. Furthermore, it is difficult to place the sutures when the segment is fully expanded. We have found it necessary to place the sutures when the lobe is partially or totally collapsed. We also have found that with expansion of the segment there is frequently disruption of the sutures. It was because of the technical difficulties that we encountered with the clamp and suture method in the removal of other pulmonary segments than the lingula, that we felt that a different way to take the lobe apart should be developed. Three years ago we developed a method of removing any of the eighteen segments without the use of lung clamps and without the use of sutures on the denuded surface. This can be accomplished without appreciable damage to the neighboring segments. In a previous report,[7] we described experiences with this procedure in twenty-three operations on twenty-one patients. That experience has now been extended to fifty-nine segmental operations on fifty patients with bronchiectasis, and to an additional eleven segmental operations for other conditions. After we had submitted our first report for publication, Clagett and Deterling[4] described a method of removing the lingula by dissecting the segment in a retrograde manner. They do not use clamps but suture the denuded surface of the lung. They suggested that their method might be applicable to other segments.

TECHNIQUE

Each bronchopulmonary segment has its own bronchus, arterial blood supply, and venous return. The bronchus and artery penetrate through the hilum of the segment into its substance where their subdivisions arborize. The venous channels in turn collect into tributaries which tend to run along the surface of the segment through the hilum back to the pulmonary veins. There are no arterial or bronchial communications from one segment to another. Occasional venous communications are encountered but the main venous return from a segment is by way of its own hilum. Rarely, partial pleural fissures occur between segments, giving additional evidence that they are true bronchopulmonary units. At all times loose areolar tissue is all that binds a segment to contiguous segments once the artery, vein, and bronchus at its hilum, and the pleura at its periphery are divided. Since this loose areolar tissue can be separated with relative ease, it is possible with certain precautions to apply to segments of pulmonary lobes the principles of individual ligation technique now universally accepted in resection of entire lobes.

The patient is prepared for operation by paravertebral injection of 0.4 per cent procaine hydrochloride into the second to eighth intercostal nerves. The parascapular region is also infiltrated. An endotracheal tube is inserted under topical cocaine anesthesia, and the saphenous vein is cannulated for infusion of fluid and blood. The operation is done with the patient in the face-down position, the diseased side slightly lowered to minimize the flow of secretions into the tracheobronchial tree. The chest is opened through a posterolateral parascapular incision, the pleura being entered through the intercostal space or rib bed most convenient to the diseased area. Adhesions are divided and the lung palpated and inspected.

The general plan of resection is the same for all segments. Exact knowledge, not only of the distribution of the arteries, veins, and bronchi to the lobes, but also of the points of origin and relations of the arteries, veins, and bronchi to the various segments, is, of course, fundamental. There are four main structures to be isolated and divided in separating off each segment: the artery, the vein, the bronchus, and the pleura.

In most instances the segmental artery is first dissected out and divided between silk ligatures. On the right, after the upper lobe has been retracted caudally and the pleura over the hilum incised, the branch to the apical segment* of the upper lobe is easily identified as the first branch of the pulmonary artery. The branch to the anterior segment of the upper lobe lies just distal to it. On the left the trunk to the apical posterior segment is found in a corresponding position. All the other segmental arteries lie in the depth of the major fissure. To approach any one of them the lower lobe is retracted posteriorly, the fissure is dissected apart, and the pleura is opened at its base. The artery terminates by dividing into three divisions, ramifying on the left into the three segments of the basal division of the lower lobe—the anteromedial, the lateral, and the posterior. On the right there are four such divisions: the anterior, medial, posterior, and lateral. Just above the basal divisions, on the left, the two branches to the lingula are found leaving the anterior surface of the pulmonary artery. In the corresponding position on the right are two branches to the middle lobe. From the posterior surface of the pulmonary artery the branch to the superior segment of the lower lobe arises just opposite or a few millimeters

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*We have adopted the nomenclature of Jackson and Huber.[5]

above the origin of the lingular or middle lobe vessels. The artery to the anterior division of the left upper lobe arises just proximal to the lingular branches. On the right the branch to the posterior division of the upper lobe is situated on the lateral surface of the pulmonary artery, slightly proximal to the origin of the middle lobe and superior segmental arteries.

The segmental vein is usually divided after the corresponding artery. These vessels are not, as a rule, difficult to identify. After the lower lobe has been allowed to fall anteriorly, and the inferior pulmonary ligament divided, the inferior pulmonary vein is identified. The dissection is carried distally along the vein to find its first bifurcation. Two tributaries of the upper division drain the superior segment of the lower lobe, while the tributaries of the lower division come from the segments of the basal divisions. The superior pulmonary vein is found anterior to the pulmonary hilum by retraction of the lung posteriorly. The upper branch receives tributaries from each segment of the upper lobe separately only a few millimeters beyond the primary bifurcation. The lower branch of the superior pulmonary vein receives two tributaries from the two segments of the middle lobe on the right or the lingula on the left. Dissection usually need only be carried a short distance out any one of these branches to identify with certainty the segment that it drains.

The segmental bronchus is now identified. At times it is more easily dissected out after the artery. Again it may be ligated early and divided later. Inflammatory tissue or lymph glands often dictate the order in which the structures are taken. The segmental bronchus lies close to and just underneath the corresponding artery. However, ordinarily it is advisable to divide the vein before the bronchus as the thin-walled veins lying close behind the bronchi are easily torn. All the lower lobe segmental bronchi and those to the middle lobe and lingula parallel the corresponding arteries closely and are easily seen as soon as the artery is divided. In the right upper lobe there is a triple branching of the upper lobe bronchus about one centimeter from the origin of the upper lobe bronchus. The three divisions serving the anterior, posterior, and apical segments are approached from the corresponding side of the hilum of the upper lobe. On the left the apical posterior bronchus and the anterior bronchus to the upper lobe lie under the corresponding artery.

When the bronchus is dissected out, an angled clamp is applied just distal to the point selected for its division. The bronchus is then cut half-way through and an end suture is inserted. A second, and in some instances a third suture is placed to tie over the end of the bronchus. The division of the bronchus is then completed and the end sutures are tied. Ideally, the stump should be closed near to the origin of the bronchus in order not to leave a pocket for the collection of secretions. All bronchi, no matter how small, are accompanied by one or two bronchial arteries and these may require ligation. The bronchial stump is tested for leakage with positive intratracheal pressure and is covered by a flap of adjacent tissue or visceral pleura if possible.

The separation of the segment from its neighbor is now begun. The distal stumps of the artery, vein, and bronchus are grasped with clamps, and slight traction is applied while the anesthetist inflates the tracheobronchial tree to fill out the adjacent segments and delineate the exact plane between the normal and abnormal. If the course of the vessels and the bronchial tree of the segment to be removed is used as a guide, it is not difficult to tease the segment from its normal neighbor by blunt dissection with the finger or a gauze pledget. The process is made easier by continuous lubrication and washing with saline. Any vein encountered crossing the cleavage plane is ligated and divided. A few terminal bronchioles may have to be stripped out of the remaining surface. When the pleura is reached, it is cut, thus completing the resection.

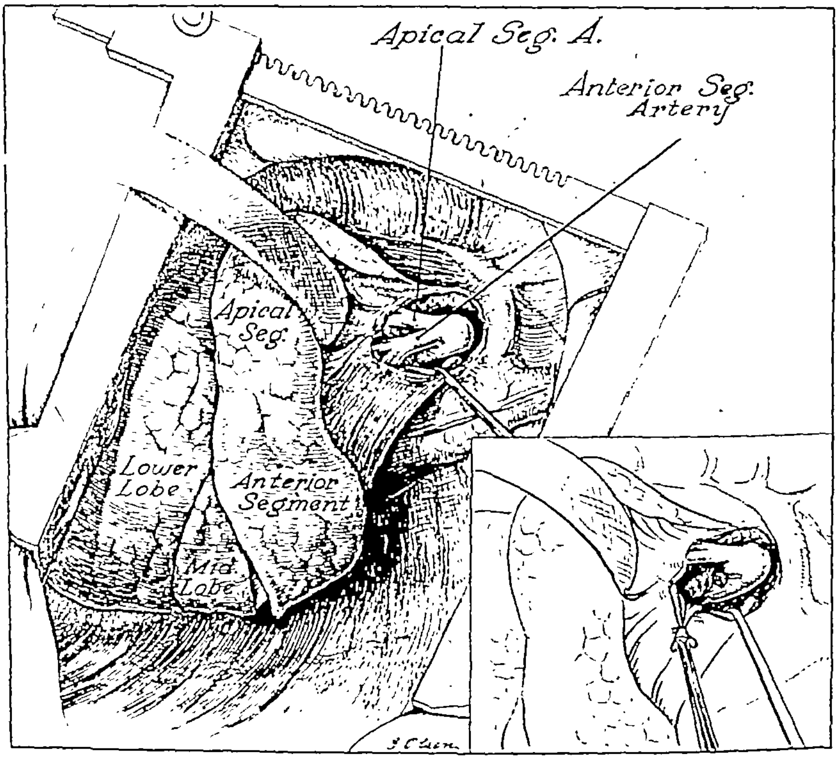

Fig. 1.—The first step in the excision of the right anterior segment. The patient is in the face-down position. The exposure and division of the segmental artery are illustrated.

Usually slight bubbling occurs from the remaining segmental surface, but it stops with the application of a moist pad for a few minutes. Bleeding from the surface has never been a problem. The pleural cavity is washed out with abundant saline and the chest wall is closed. Two catheters are brought out through the incision for underwater drainage with suction applied at a negative pressure of 6 to 10 cm. of water. Care is taken to see that the remaining lung tissue is well filled out as the closure is made.

In an earlier report,[7] illustrations were included which showed the important anatomic relations at the various stages of segmental resection of both the basal segments of the left lower lobe and the lingular segment of the left upper lobe.

In this paper, Figs. 1, 2, 3, and 4 show the stages of resection of the anterior segment of the right upper lobe. Fig. 1 shows the upper lobe retracted caudally,

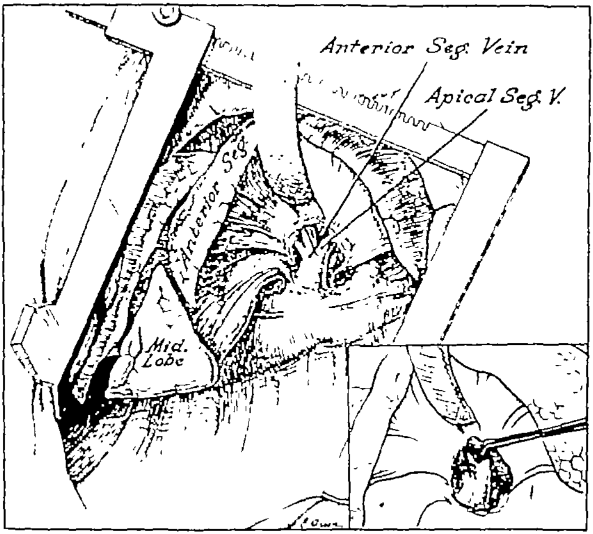

Fig. 2.—The second step in the excision of the right anterior segment. The anterior segmental vein is exposed and divided.

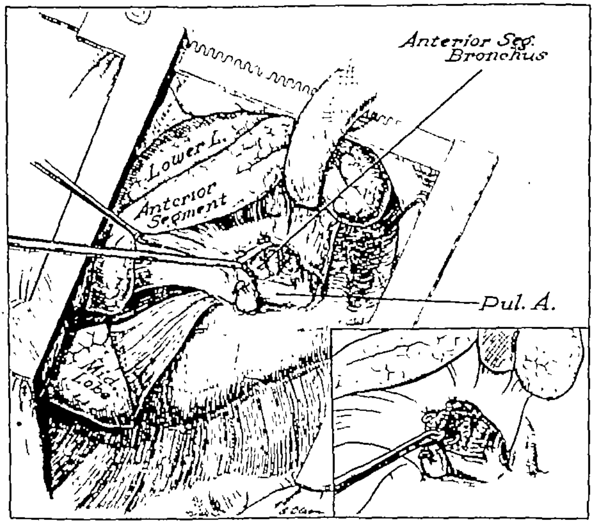

Fig. 3.—The third step in the excision of the right anterior segment. The segmental bronchus is exposed and divided.

exposing the superior aspect of the right hilum. The branches of the right pulmonary artery to the superior and anterior segments of the upper lobe are demonstrated. Insert Fig. 1 shows the branch to the anterior segment divided. Fig. 2 shows the entire lung retracted posteriorly exposing the superior pulmonary vein. The venous tributaries from the upper lobe are dissected out. Insert Fig. 2 shows the tributary from the anterior segment divided. Fig. 3 shows the upper lobe bronchus at its segmental bifurcation exposed by posterior and inferior retraction of the lobe. In Insert Fig. 3 the anterior segmental bronchus is divided. Fig. 4 shows separation of the anterior segment from the neighboring posterior and superior segments. Insert 4 shows the preoperative relations of the anterior segment.

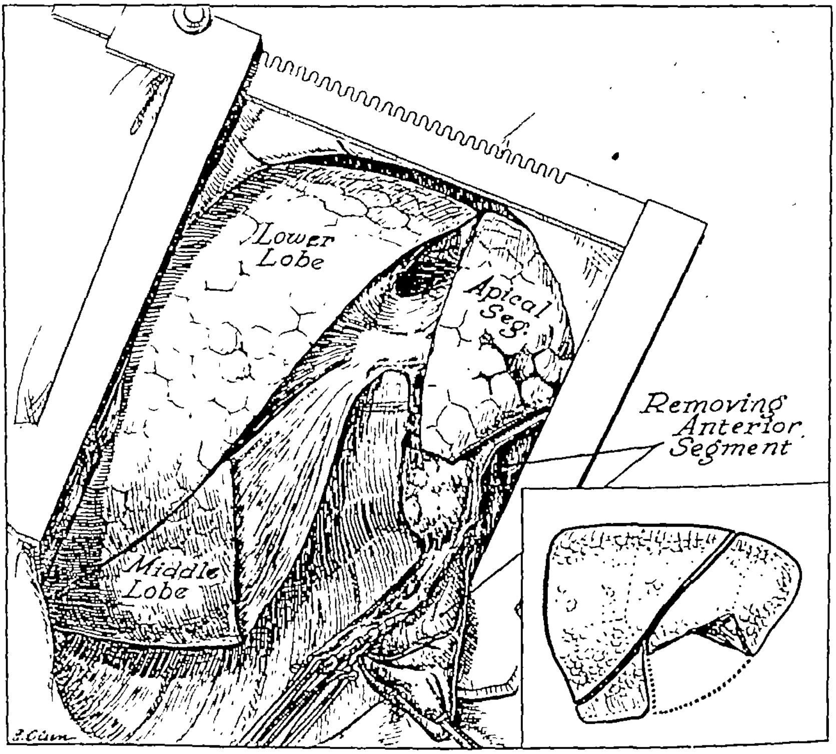

Fig. 4.—The fourth step in the removal of the right anterior segment. The retrograde separation of the segment and development of the intersegmental plane. Note that no lung clamps are used. The insert shows the appearance of the lateral surface of the lung after removal of the anterior segment.

Figs. 5, 6, 7, and 8 show the corresponding stages of resection of the superior segment of the left lower lobe. Fig. 5 shows dissection in the depth of the interlobar fissure. The left pulmonary artery and its segmental branches in the fissure are seen. Insert Fig. 5 illustrates division of the branch to the superior segment of the lower lobe. In Fig. 6 the lower lobe is dropped forward and the inferior pulmonary vein is dissected out. Insert Fig. 6 shows division of the tributaries from the superior segment. Under the divided vein Fig. 7 shows dissection of the branch bronchus to the superior segment of the lower lobe and Insert Fig. 7 shows its division. Separation of the segment is illus-

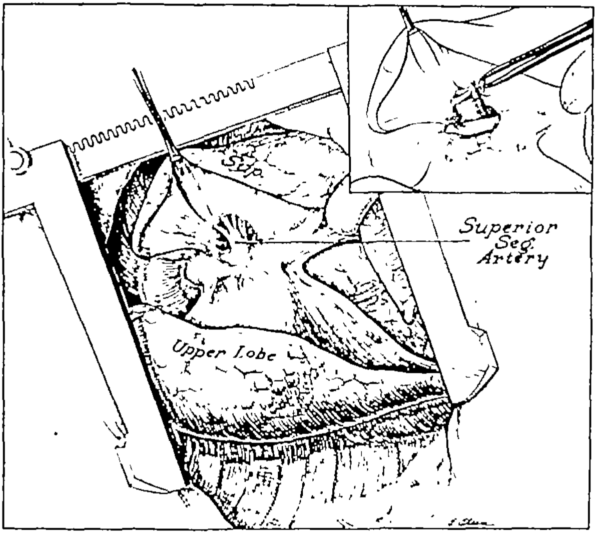

Fig. 5.—The first step in the removal of the superior segment of the left lower lobe. The exposure is shown with the patient in the face-down position. The segmental artery is exposed and the insert shows the vessel after its ligation.

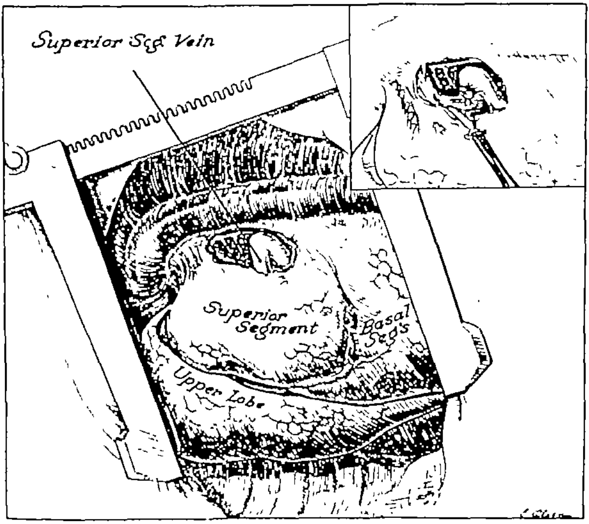

Fig. 6.—The second step in the excision of the superior segment of the left lower lobe. The segmental vein is exposed.

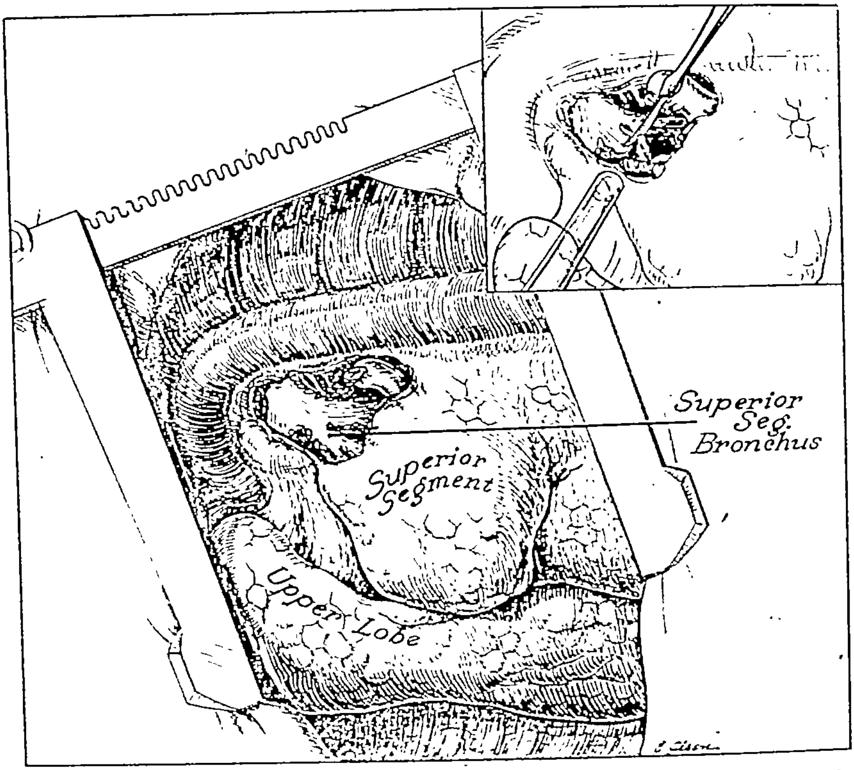

Fig. 7.—The third step in the excision of the superior segment of the left lower lobe. The insert shows the division of the segmental bronchus.

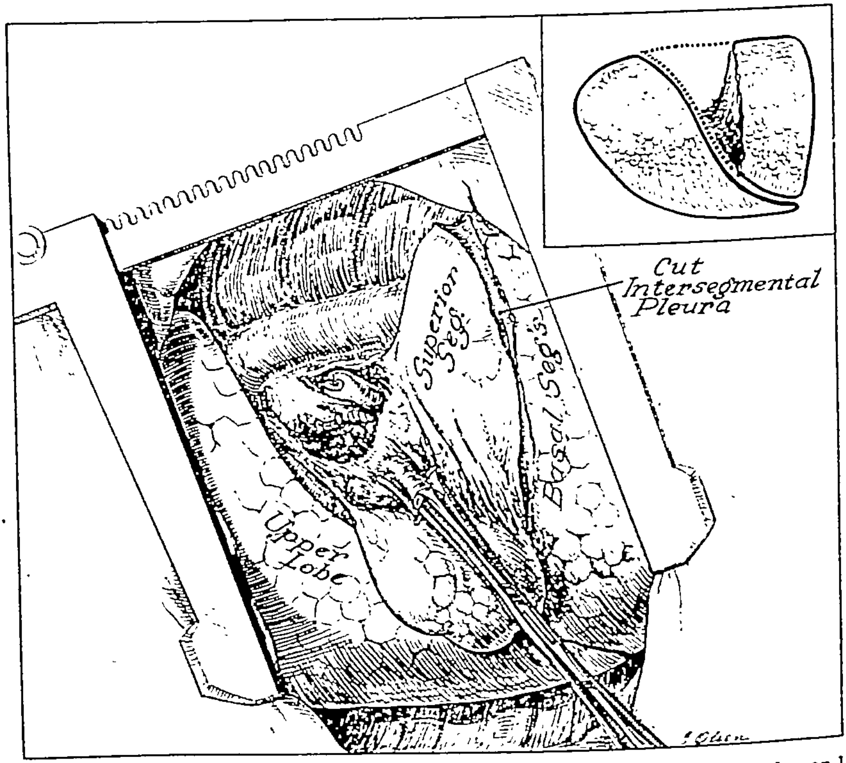

Fig. 8.—The final step in the excision of the superior segment of the left lower lobe. Note that no clamps are being used. The intersegmental plane is developed from the center toward the periphery after the segmental artery, vein, and bronchus, and the visceral pleura have been divided. Note that no lung clamps are used.

trated in Fig. 8 and Insert Fig. 8 shows the original relations of the removed segment.

POSTOPERATIVE CARE

Postoperative care does not differ from that of routine lobectomies. The primary concern is the maintenance of a good airway and rapid re-expansion of the remaining segments. Oxygen is not usually needed. Coughing is encouraged to bring up secretions. This is often helped by manual support of the chest. Transtracheal suction or less frequently bronchoscopy may be needed if the patient is unable to raise secretions. Signs of atelectasis are watched for and promptly treated. Frequent x-ray or fluoroscopic check of the chest is made to note any pneumo- or hydrothorax. If these cannot be eliminated by manipulation of the tube, chest aspirations are done. The tubes are usually removed in two to three days, but are kept in place if there is evidence of air leak or if the lung has not properly re-expanded.

SUMMARY OF SEGMENTAL RESECTIONS

From March, 1945, through April, 1947, we have carried out a total of seventy segmental pulmonary resections. Of these, fifty-nine were carried out on fifty patients for bronchiectasis, and eleven were done for other reasons. In the group of patients with bronchiectasis, six additional total lobectomies were carried out, making a total of sixty-five operations in these fifty patients.

BRONCHIECTASIS

Analysis of the patients with bronchiectasis shows an age range of 7 to 55 years, with seven over 40 years of age. The duration of symptoms ranged up to 48 years. A tabulation of the frequency of involvement of each bronchopulmonary segment in this group is shown in Table I and reveals nearly all the disease in the dependent basal segments of the lower lobes, the lingula, and the middle lobe. A corresponding analysis of the operative procedures in the same group is shown in Table II. It will be noted that in forty of the fifty-nine opera-

TABLE I. FREQUENCY OF INVOLVEMENT OF PULMONARY SEGMENTS IN REPORTED GROUP OF FIFTY CASES OF BRONCHIECTASIS

LOBE	SEGMENT	NO. OPERATIONS
Right upper	Anterior	2
Right upper	Superior	0
Right upper	Posterior	0
Right middle	Medial	23
Right middle	Lateral	23
Right lower	Superior	0
Right lower	Basal*	26
Left upper	Anterior	1
Left upper	Apical-Posterior	1
Left upper	Lingula	
	Superior division	27
	Inferior division	31
Left lower	Superior	3
Left lower	Basal*	37

*In only one case was the disease limited to one basal segment. In the others there were two or more involved. It has been impossible to determine accurately the extent of involvement of individual basal segments in all cases. Therefore we have grouped them together.

TABLE II. TABULATION OF FIFTY-NINE SEGMENTAL OPERATIVE PROCEDURES FOR BRONCHIECTASIS

LOBE	SEGMENT	NO. OPERATIONS
Right lower	Basal group	4
Right lower	Posterior basal	1
Right lower and Middle	Basal	13
Right middle and Right upper	Anterior	1
Left lower	Basal	9
Left lower and Lingula	Basal	22
Lingula		2
Left lower and Lingula	Basal Inferior division	4
Left lower	Superior	1
Left lower and Lingula		1
Lingula and Left upper	Anterior	1

tions segments were removed from more than one lobe. Twenty-four of the fifty patients have proved bilateral bronchiectasis and thirteen have had bilateral operations, although only nine were segmental on both sides.

As might be expected, an increase in complications such as difficulties with re-expansion and fluid accumulations were encountered following segmental resections. We feel, however, that certainly in the presence of bilateral disease, and possibly even in well-localized disease, the conservation of healthy lung tissue well compensated for the added trouble in aftercare. The only death in the group came as a result of a complication unrelated to segmental resection on the second side. At that time we were using fine stainless steel wire to close the bronchial stump. The cut end of a suture eroded through the pericardium into the pulmonary artery, causing a fatal hemopericardium. The use of sutures of wire in segmental bronchi has been discontinued. Empyema occurred fourteen times, or in 23.7 per cent of fifty-nine operations. All except one patient required drainage and he was treated by aspiration and injection of penicillin. Some cases followed known air leaks and others were independent. Three times re-exploration was done because of persistent pneumothorax despite suction drainage. In two the leak was from the segmental surface and in one from a bronchial stump. The average hospitalization was, of course, prolonged. This represents an early experience and covers the developmental period. We are confident that complications will become less frequent with an increase in the skill of carrying out the dissection.

A large proportion of the end results (Table III) have been satisfactory. Those patients who are in good health and are virtually relieved of symptoms are recorded as "good." Those with definite improvement but with some residual sputum are recorded as "improved." Only two are recorded as "poor."

TABLE III. RESULTS IN SEGMENTAL RESECTION OF FIFTY CASES OF BRONCHIECTASIS

	GOOD	IMPROVED	POOR	INADEQUATE FOLLOW-UP
Unilateral cases	16	7	0	4
Bilateral cases				
Unilateral *operation*	3	4	1	2
Bilateral operation	4	4	1*	4

*This case was the postoperative death.

One of these was the patient who died postoperatively. Ten are recorded as inadequately followed because recent information is not available or they have been operated on within the last three months. As would be expected, the best results are found among those with unilateral involvement: sixteen are good, seven improved, and none poor. Among the bilateral cases with only unilateral operation, three are good, four improved, and one poor. Improvement in this group is expected when second operations are completed on some of those not completely relieved of symptoms. Of the bilateral cases with bilateral operation, four are good, four improved, and one unimproved. The results with unilateral operation for bilateral disease appear comparable to those with bilateral operation because two patients with minimal contralateral disease are completely relieved and another is improved by a unilateral operation. The numbers are of course not statistically significant.

SEGMENTAL OPERATIONS FOR LESIONS OTHER THAN BRONCHIECTASIS

Segmental resections for lesions other than bronchiectasis have been done eleven times for the following:

Tuberculosis	4
Chronic lung abscess	3
Pulmonary cyst	2
Benign tumor	1
Metastatic tumor	1

These are of sufficient interest to warrant brief abstracts:

CASE 1.—E. M. was a 45-year-old woman with a known history of tuberculosis dating back to 1930. An examination because of pain in the left shoulder and weight loss of forty-four pounds revealed a tuberculoma in the left upper lobe. At operation on Jan. 11, 1946, the lesion was resected with the posteroapical segment of the left upper lobe. No thoracoplasty was done. She did well for several months but developed bilateral reactivation which has, however, responded to sanatorium treatment, and she was in good condition in April, 1947.

CASE 2.—G. F., a 39-year-old man with a history of tuberculosis dating back to 1942, had a large cavity in the left upper lobe. There was little reaction around the cavity and no evidence of disease elsewhere. The lesion with the posteroapical segment was resected March 8, 1946. He developed contralateral and ipsolateral spread postoperatively, and then a tuberculous empyema and bronchopleural fistula. Drainage, thoracoplasty, and attempted closure of the fistula were done April 15, 1946. Despite a prolonged course his general condition is now good, his sputum is negative, the fistula closed, and the chest wall is healed.

CASE 3.—D. J., a 24-year-old woman, gave a five-year history of bilateral tuberculosis. The left-sided disease was quiescent but the right upper lobe contained multiple cavities which did not close despite a good pneumothorax. On Dec. 19, 1945, the right upper lobe was resected together with a nodular superior segment of the lower lobe. This was followed by a thoracoplasty Feb. 19, 1946. Postoperatively a small pyogenic empyema developed which responded to aspiration and penicillin injections. A period of sanatorium care followed and she was last reported in excellent condition in February, 1947.

CASE 4.—J. S., a 32-year-old woman, gave a nine-year history of tuberculosis. Cough, positive sputum, and weakness persisted. She had a contracted right upper lobe and the superior segment of the right lower lobe under a pneumothorax. On bronchoscopy gross disease was noted in the right upper lobe bronchus. The right upper lobe and superior segment of the lower lobe were removed Oct. 2, 1945. The pathologist reported fibrocaseous tuberculosis without cavitation. Thoracoplasty was done in November, 1945, in two stages. No complications occurred until several months later when a short febrile episode was relieved by coughing up some purulent material probably from a stump abscess. Her condition was reported as excellent in February, 1947.

CASE 5.—E. Q. was a 40-year-old woman with a history of repeated hemoptyses. Appropriate diagnostic study showed a chronic lung abscess which was removed on Jan. 21, 1946, by resection of the superior division and the posterior and medial basal divisions of the right lower lobe. The postoperative course was uneventful and she was in excellent health when last seen just one year later. The pathologic report was actinomycosis. We would have hesitated to do a segmental resection had the etiology been known.

CASE 6.—G. B. was a 34-year-old man with a nine-month history of cough, expectoration, and hemoptysis, in whom a diagnosis of chronic lung abscess was made. The inflammatory tissue was removed by segmental resection of the superior segment of the right lower lobe and the posterior segment of the right upper lobe on Nov. 16, 1945. He developed a mediastinal empyema which was drained on a second admission on Jan. 16, 1946. When last seen Nov. 14, 1946, his condition was excellent.

CASE 7.—J. L. was a 39-year-old man with a five-month history of chronic lung abscess and corresponding findings. The right upper and middle lobes were resected together with the superior segment of the right lower. He developed a fulminating bilateral pneumonia on the fourth postoperative day and died.

CASE 8.—A. M., a 39-year-old man, complained of incapacitating progressive dyspnea following an injury. X-rays showed a bullous cyst seven inches in diameter, filling the left upper chest. At operation Feb. 18, 1947, this was found in the posteroapical segment of the left upper lobe. A segmental resection was done and the normal lung decorticated. There were no complications and he was restored to normal health two months later.

CASE 9.—J. R., an 18-year-old boy, complained only of hemoptysis. A cavity with fluid thought to be an abscess in the superior division of the right lower lobe was drained. At operation May 1, 1947, it proved to be a pulmonary cyst in the posterior segment of the right upper lobe; it was removed with this segment. The postoperative course was uneventful.

CASE 10.—W. F., a 52-year-old man, complained of dyspnea and wheeze. By x-ray a tumor was demonstrated in the superior segment of the left lower lobe. It proved at operation Jan. 25, 1946, to be a hamartoma, and was removed by segmental resection. Eight months later he was in normal health.

CASE 11.—A. T., a 29-year-old woman, complained of chest pain and hemoptysis. X-ray demonstrated a tumor in the lingula. What was diagnosed as a myxofibroma was removed from the heel in 1942. At operation April 29, 1946, a tumor was removed with the lingula. The microscopic diagnosis was liposarcoma. No operative complications occurred. Although asymptomatic, a second metastasis was found and removed Jan. 17, 1947, from the mediastinum. The patient was in good health in April, 1947.

SUMMARY AND CONCLUSIONS

Our experience with a new method of resection of the pulmonary segment has now been extended to seventy operations. Fifty-nine were for bronchiectasis, and eleven for other conditions. The method consists essentially of isolating and dividing the artery, vein, and bronchus to the segment, which is then gently teased from its neighbor. The pleura is divided as the final step. The importance of conserving all normal bronchopulmonary segments has been brought out. Among the group with bronchiectasis, the complications have been greater than in total lobectomy. However, the end results have been satisfactory in the great majority of all groups of patients. We therefore feel that certainly in a patient with bilateral disease, segmental resection saving all normal segments is not only justified, but to conserve all possible respiratory function is obligatory. Even in well-localized unilateral bronchiectasis the conservation of normal lung may justify the increased morbidity. In chronic inflammatory processes such as chronic lung abscess or tuberculosis, our limited experience does not warrant a conclusion and we are hesitant to recommend it at present. In noninflammatory processes such as cysts and benign or metastatic tumors, a few experiences have been without complication. We are hopeful of developing a satisfactory method of sealing the raw surface after segmental resection. Pleural flaps, fibrinfoam, or gelatin sponge sheets are possible substances which may be eventually found satisfactory for the purpose.

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DISCUSSION

DR. RALPH ADAMS, Boston, Mass.—I rise to restate certain historical facts about the technical development of segmental pulmonary resection.

This technique, so beautifully illustrated by a recent article by Overholt and Langer, and described here today by Overholt, Betts, and Woods, was taught to me by Dr. Edward Churchill of Boston in 1938. Dr. Churchill began his segmental pulmonary resection work in 1937, just ten years ago. Most of you, no doubt, remember the article by Churchill and Belsey about that time.

By 1938 the principles of conduct in resecting a division of the lower lobe or a segment other than the lingula of the upper lobe were established and placed in practice by Dr. Churchill. After leaving my assistantship with him at the Massachusetts General Hospital in 1941, I have had opportunity to apply the method in thirty-one cases in the New England Deaconess and Baptist Hospitals.

In seventy-three cases of bronchiectasis, a segmental pneumonectomy of various types was done in thirty-one cases. In the seventy-three cases there were six instances of bronchial fistula with empyema. Four of those occurred in the segmental resections; they all healed spontaneously. The two that failed to heal spontaneously were not in segmental types of resection.

In the seventy-three cases there has been no hospital mortality, and, fortunately, no subsequent mortality.

DR. DAVID H. WATERMAN, Knoxville, Tenn.—Shortly after Dr. Overholt first began using this technique of peeling the segmental portion to be removed away from the hilus, I became interested in it at his suggestion. We have had a much smaller series, only about one-third of his, but have been very enthusiastic about the procedure, and have felt that it has a very definite place.

We feel very strongly that it is a fundamental concept in surgery to preserve all normal tissue possible. Certainly this is true of the lung. We do not know when the patient is going to need that conserved lung tissue later. I think that it is well worth the extra effort and trouble to save it.

At this stage of the game, we also feel that if we can become proficient enough at resecting these segments in the good-risk patient, we will later be able to take care of severe bilateral bronchiectasis patients who would otherwise be inoperable if the uninvolved segments were not saved. In our own experience we know we have gotten through a number of patients who could not have survived complete lobectomy with its resultant loss of functional tissue.

We have not used the operation in children before the age of puberty, feeling that probably the additional risks, both in length of surgery and in complications were not warranted, since the normal hypertrophy of lung tissue coincident with chest enlargement would compensate adequately.

We have never bothered to use it on middle lobes or in tuberculosis patients, but have used it in lung abscesses, particularly in removing the apex of the lower lobe.

We agree there are more complications, as Dr. Woods has pointed out. We have had the same trouble he has had with leakage from the denuded surface. Oxycel-gauze left in place has been of aid.

We have also had a little more trouble, I think, with atelectasis of the remaining segments of the operated lobe. The first case we did, in which we preserved a superior segment of a lower lobe, required two bronchoscopies postoperatively. The lower lobe would drop down, kink, and become atelectatic, but would aerate after bronchoscopy. Subsequent to that time, when we have preserved a superior segment of a lower lobe, we have placed sutures along the fissure to keep it in place. Since then we have never had this complication.

One important step in technique, and I know Dr. Overholt and his associates subscribe to it, is the ligation of the bronchus as close to the preserved branch as possible. On our third case, in removing basilar segments of the lower lobe, we ligated too low, leaving a stump below the superior division. The patient, although clinically much benefited, had a massive hemoptysis some months after surgery. We were in the embarrassing position of having to operate again to remove the stump.

DR. PAUL C. SAMSON, Oakland, Calif.—Anatomic segmental resection and its surgical refinements, such as have been demonstrated today are, I believe, a definite addition in the treatment of bronchiectasis.

In the past few months, Dr. Dugan and I have had the opportunity of using this technique in some fifteen cases. All were for bronchiectasis, except one for chronic lung abscess in an apical segment of the right lower lobe and one for tuberculosis, in which the right upper lobe, middle lobe, and the apical and subapical segments of the lower lobe were removed.

I believe it will be of interest to show two films which demonstrate the fact that bronchograms must be made with great accuracy if we are to delineate these segments.

(Slide.) Shown here is an example of a probable post-abscess bronchiectasis, in the ordinary frontal view. The exact location of the bronchiectasis cannot be told from this projection, but in the lateral view it is obviously in the apical (or superior) segment of the lower lobe.

In bronchography, I think one should stress—when we are delineating segments—that the lateral roentgenogram is only of value when one side is filled at a time.

(Slide.) This is a particularly good demonstration, as was shown in the movie, of what happens to an apical segment when it distends following disease and shrinkage in the basal segments. We see again a small amount of bronchiectasis in the lower lobe on the right side. In the lateral projection we see that it is limited to the basal segments, and here is a large apical segment which occupies, as you can see, a very considerable proportion of the lower section of the chest. Even though it was a one-sided lesion, in an effort to increase our technical ability, a segmental resection of the basal segments was done, and this apical segment expanded very well, and on the table reached the diaphragm.

As the essayists have pointed out, the complications are somewhat more frequent if segmental resection is done. We have not found that they have been particularly serious, but one must expect a slightly increased number of patients who have excessive secretions in their bronchial tree following operation, a slightly increased number of patients who have minor air leaks, and, I believe, a definitely increased number of localized empyemas.

In a series of over 150 consecutive lobectomies which Dr. Dugan and I have done, we have had five empyemas in the total series. Three of those were associated with the group in which segmental resections were done.

DR. F. M. WOODS, Boston, Mass.—We have not, as I said, had particular difficulty with re-expansion of the remaining segments. However, on a number of occasions we have had to do bronchoscopies for transient atelectasis or for patients who had difficulty in raising secretions. The obvious defect in this procedure, of course, is the raw surface which is left after the segmental resection, and it is to be hoped that in the future some satisfactory method will be developed to cover this so that leaks and the egress of infection from the tracheobronchial tree can be satisfactorily taken care of, and convert this into an operation as safe as a total lobectomy.

EXPLORATORY THORACOTOMY IN THE MANAGEMENT OF INTRATHORACIC DISEASE

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MAJOR MARTIN L. BRADFORD,† MEDICAL CORPS, ARMY OF THE UNITED STATES (BY INVITATION), AND
COLONEL HUGH W. MAHON,‡ MEDICAL CORPS, REGULAR ARMY (BY INVITATION)

DURING recent years mass x-ray surveys have been extended by both governmental and private agencies to the point that there is scarcely an individual in the United States who lacks the opportunity to have a chest examination by x-ray. The experience gained from such studies indicates that among apparently normal working adults, approximately 1.4 per cent are found to give x-ray evidence of reinfection tuberculosis and one in eighty-nine show abnormal nontuberculous findings. Studies of consecutive hospital admissions reveal that 8 to 10 per cent of patients admitted to a hospital have evidence of thoracic disease.

It is apparent that this means of discovering pathologic lesions in apparently healthy persons at a stage prior to the onset of symptoms presents an exciting opportunity to chest surgeons for the early diagnosis and treatment of malignant neoplasms. It is at the same time a challenge to the medical profession to clarify its ideas concerning differential diagnosis and treatment of intrathoracic lesions. Time is precious and procrastination is disastrous. Each clinical problem must be approached in an orderly way and brought to definitive treatment as expeditiously as possible. It is the purpose of this communication to discuss the information derived from accepted methods of differential diagnosis and to evaluate the place of exploration of the thorax in the management of obscure lesions of the chest.

EXPERIENCE

During the period between September, 1942, and April, 1947, there were 200 exploratory thoracotomies of the chest performed for obscure intrathoracic disease at Fitzsimons General Hospital, Denver, Colo. Table I shows the location of the lesions explored and indicates the number and percentage of malignant tumors discovered. Table II reveals the pathologic diagnoses of the tissues removed.

The patients in this series were predominantly male and approximately 90 per cent were men in service in World War II. The other 10 per cent were veterans of World War I. (See Figs. 1 to 19.)

From the Surgical Service of Fitzsimons General Hospital, Denver, Colo.

Read at the Twenty-Seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

*Chief of Surgical Service, Fitzsimons General Hospital.

†Chief of Chest Surgery Section, Fitzsimons General Hospital.

‡Chief of the Laboratory Service, Fitzsimons General Hospital.

TABLE I. EXPLORATORY THORACOTOMY

LOCATION OF LESIONS	NO. CASES	NO. MALIGNANCIES	PER CENT
I. Mediastinal	73	12	16.4
II. Intrapulmonary	113	29	25.6
III. Extrapulmonary (Exclusive of mediastinal and vascular)	8	2	25.0
IV. Heart and great vessels	6	0	0
Total	200	43	21.5

TABLE II. EXPLORATORY THORACOTOMY

PATHOLOGIC DIAGNOSIS	NUMBER		
I. Mediastinal Lesions			73
A. Lymph nodes		24	
1. Hodgkin's	3		
2. Lymphoma, giant follicular hyperplasia	1		
3. Boeck's sarcoid	6		
4. Tuberculous lymphadenopathy	8		
5. Mediastinitis	6		
B. Congenital cysts		22	
1. Dermoid	3		
2. Teratoma	3		
3. Pericardial celomic	8		
4. Bronchial	7		
5. Esophageal	1		
C. Acquired cyst		1	
1. Cystic hematoma	1		
D. Tumors		25	
1. Connective tissue	4		
2. Neurogenic	8		
3. Thymic	7		
4. Esophageal	1		
5. Primary carcinoma	5		
E. Intrathoracic goiter		1	
II. Intrapulmonary Lesions			113
A. Tuberculosis		40	
1. Active	16		
2. Tuberculoma	24		
B. Bronchogenic tumor		29	
1. Malignant	24		
2. Benign	5		
C. Hamartoma		1	
D. Primary sarcoma		1	
E. Metastatic carcinoma and sarcoma		1	
F. Amoebic abscess		1	
G. Congenital bronchogenic cyst		13	
H. Parasitic lesion		1	
1. Taenia echinococcus	1		
I. Fungus lesion		6	
1. Actinomycosis	2		
2. Blastomycosis	1		
3. Coccidioidomycosis	3		
J. Pneumonitis		13	
K. Atelectasis		3	
L. Aneurysm		1	
M. Interlobar empyema		2	
N. Apical empyema		1	
III. Extrapulmonary Lesions			8
A. Pleural malignancy		1	
B. Liver abscess		2	
C. Diaphragmatic hernia		3	
D. Tumor of diaphragm		1	
E. Tuberculous granuloma of pleura		1	
IV. Heart and Great Vessel Lesions			6
A. Aneurysm of heart		1	
B. Aneurysm of great vessels		5	

Fig. 1.

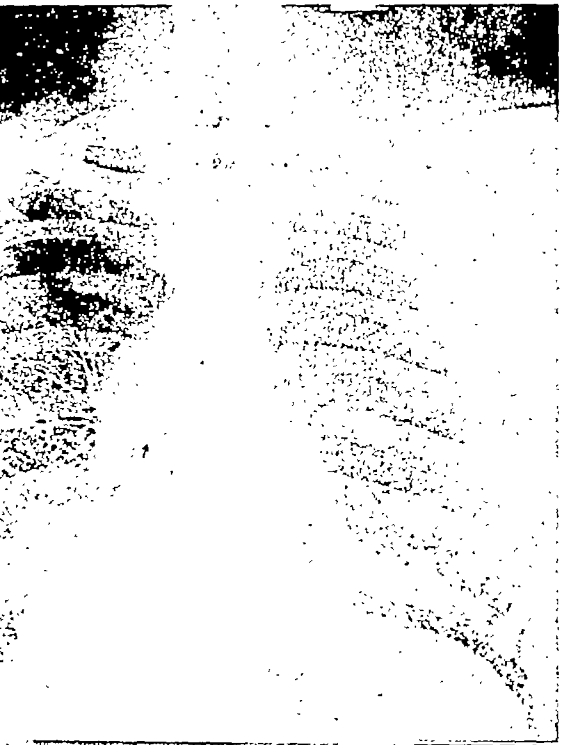
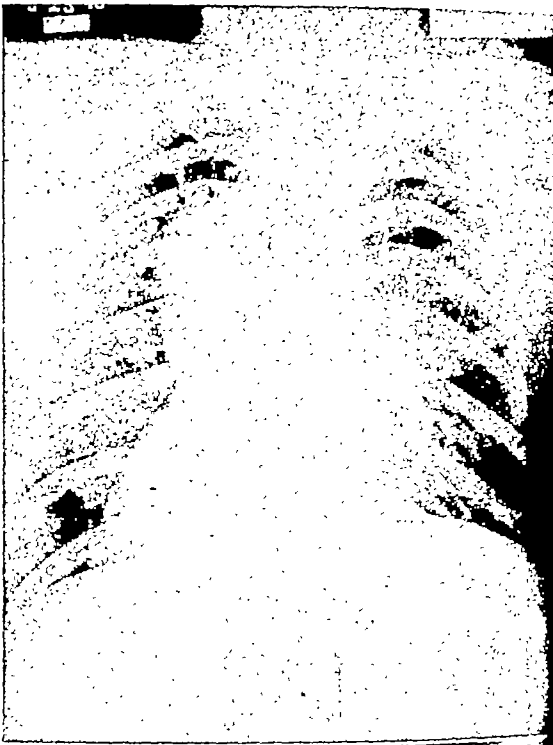


Fig. 2.



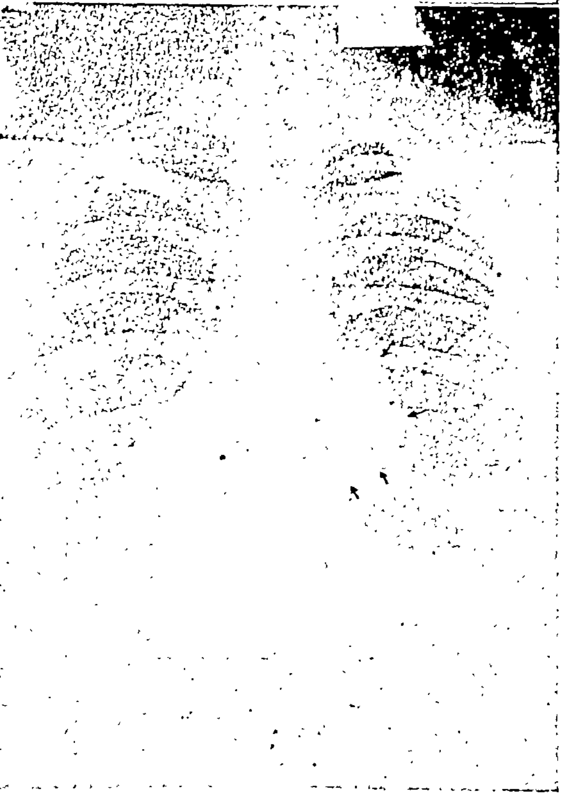


Fig. 3.

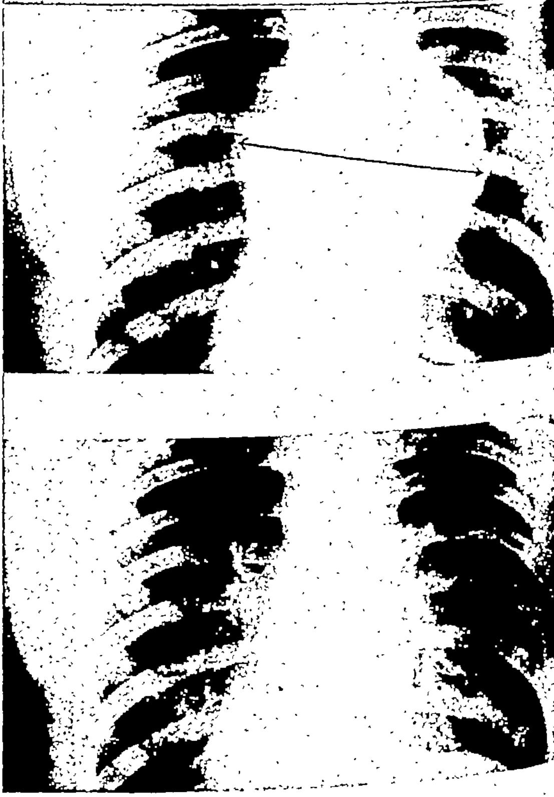


Fig. 4.

Mediastinal Lesions

Fig. 1.—Giant follicular hyperplasia.
Fig. 2.—Benign teratoma.
Fig. 3.—Intrathoracic goiter.
Fig. 4.—Thymic carcinoma. *A*, Before x-ray therapy; *B*, response to x-ray therapy.

Fig. 5.

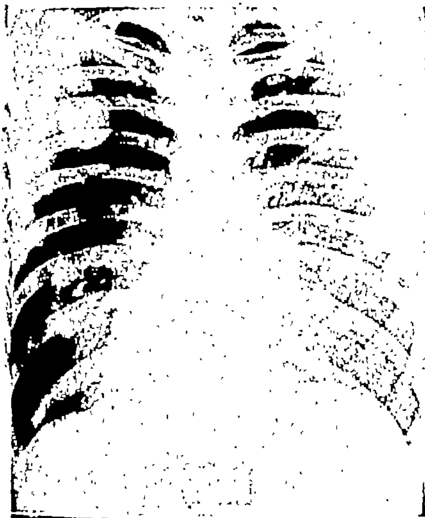
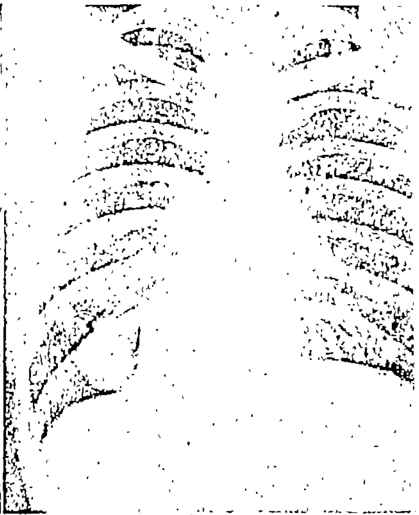


Fig. 6.



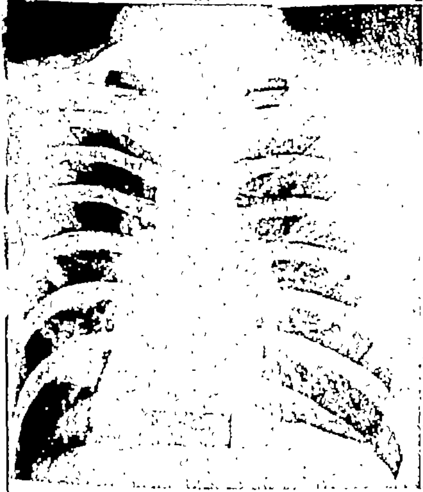


Fig. 7.

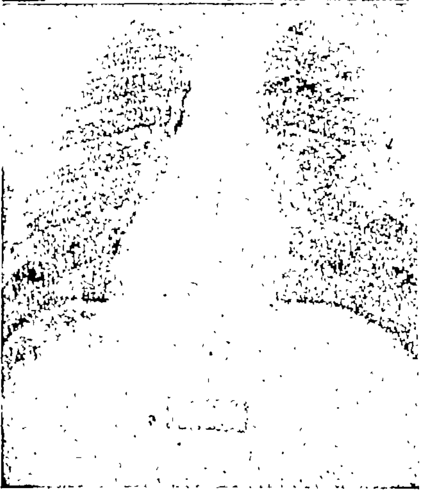


Fig. 8.

Intrapulmonary Lesions, Benign

Fig. 5.—Coccidioidomycotic granuloma.
Fig. 6.—Venous aneurysm, left inferior pulmonary vein.
Fig. 7.—Congenital bronchogenic cyst.
Fig. 8.—Parasitic lesion taenia echinococcus.

Fig. 9.

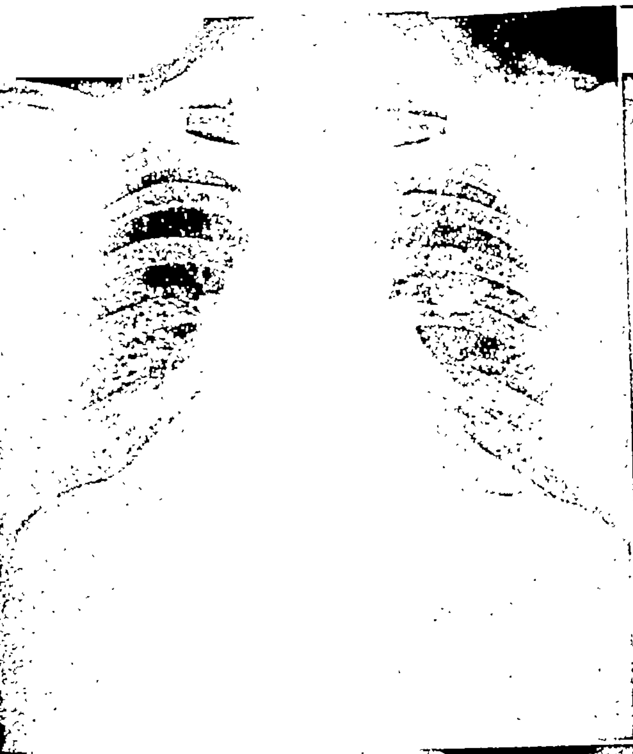
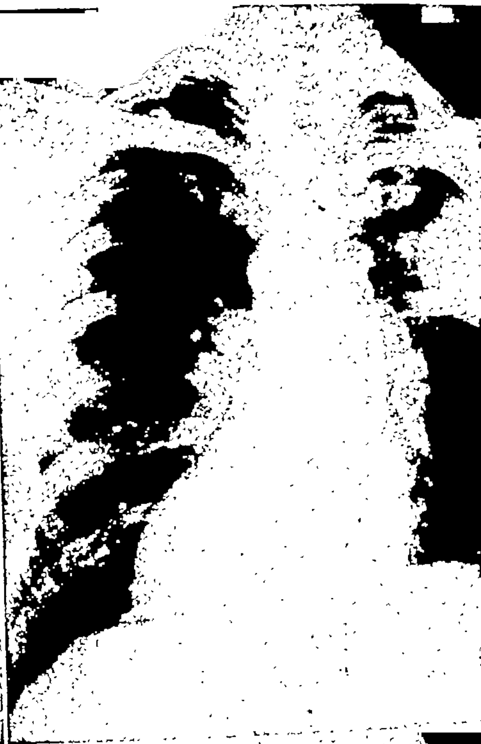


Fig. 10.



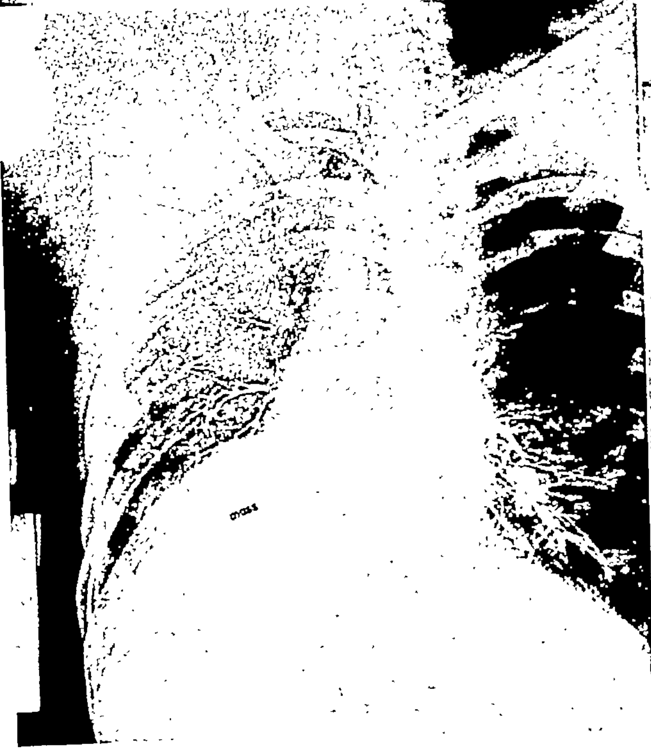


Fig. 11.

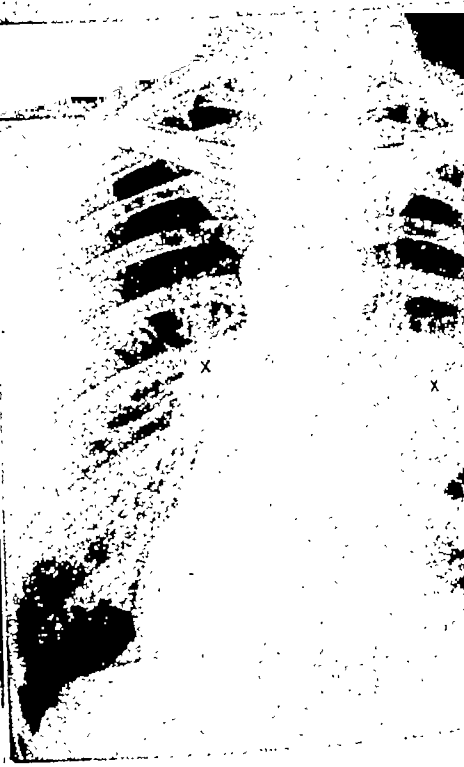


Fig. 12.

Intrapulmonary Lesions, Malignant

Fig. 9.—Adenoma.
Fig. 10.—Bronchogenic adenocarcinoma.
Fig. 11.—Fibrosarcoma.
Fig. 12.—Bronchogenic squamous-cell carcinoma.

Fig. 13.

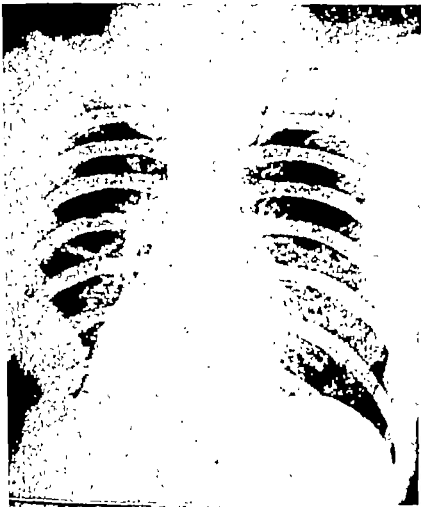
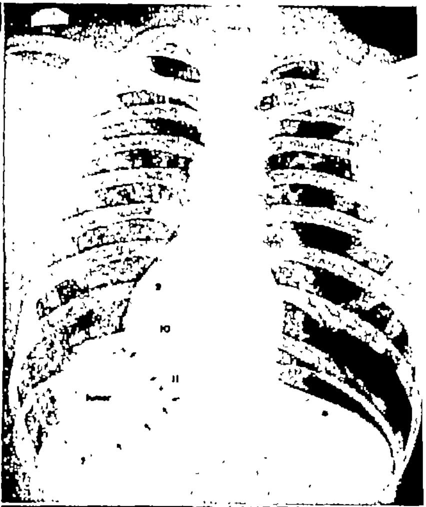


Fig. 14.



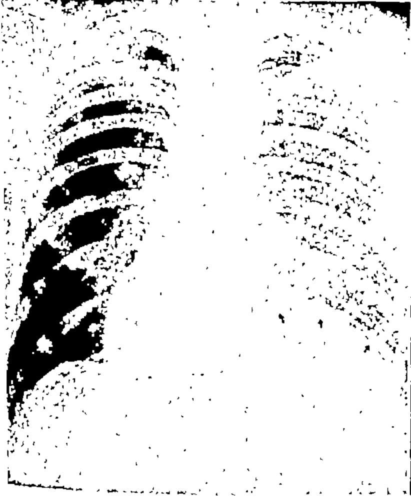


Fig. 15.

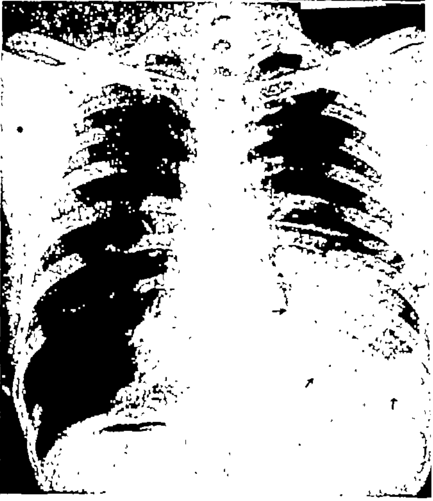
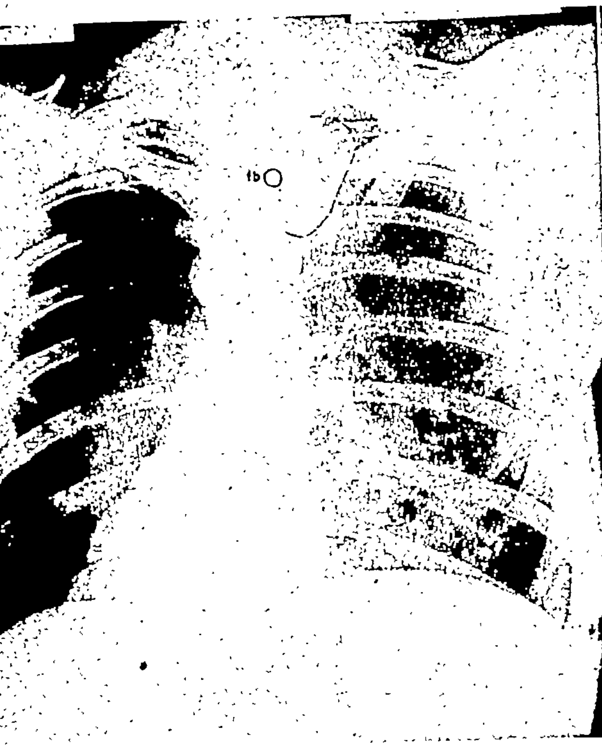
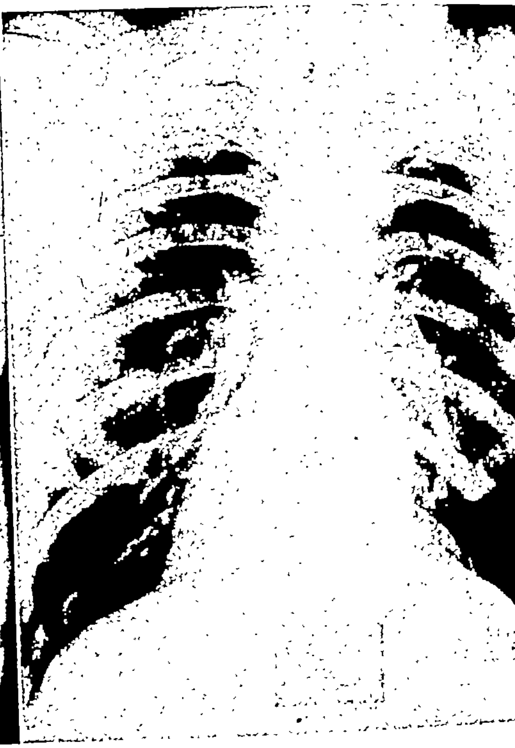


Fig. 16.

Extrapulmonary Lesions, Nonmediastinal or Vascular

Fig. 13.—Diaphragmatic omental hernia.
Fig. 14.—Fibroangioendothelioma of diaphragm.
Fig. 15.—Liver abscess.
Fig. 16.—Endothelioma of pleura.





Heart and Great Vessel Lesions

Fig. 17.—Traumatic aneurysm, innominate artery (outlying foreign body lodged in spine).
Fig. 18.—Congenital aneurysm of aorta.

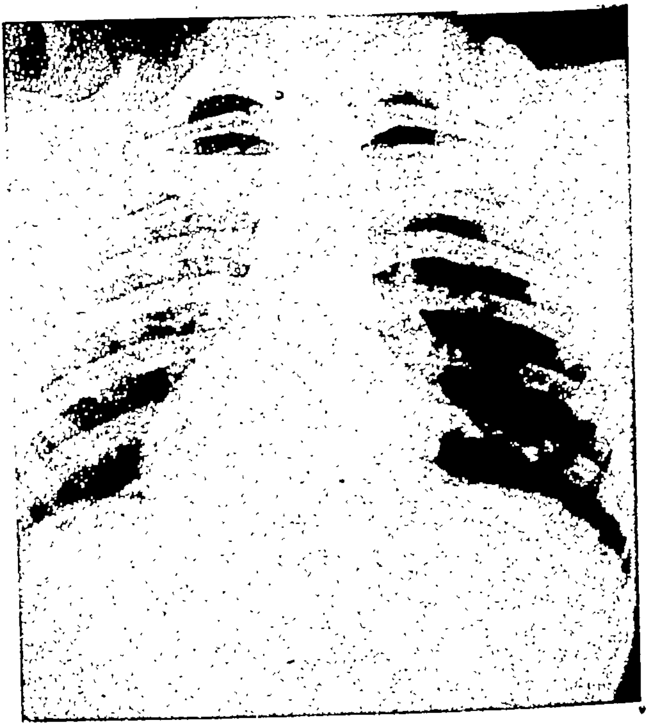


Fig. 19.—Aneurysm of right ventricle.

HISTORY AND PHYSICAL EXAMINATION

The studies of Gebauer[10] indicate that the symptoms of bronchogenic carcinoma have their onset early in the disease. However, the impression gained from this group of cases is that the symptoms of thoracic neoplasms are either absent or of such low intensity early in the disease that they are of negligible value either for causing the patient to consult his physician or for impressing the physician with the seriousness of the malady.

Except for the fortunate patient who develops bronchial obstruction with secondary pulmonary suppuration early in the disease, physical examination is not contributory until the patient has reached the stage where he is of interest only to the statistician and the pathologist. In an occasional case, a localized wheeze or segment of atelectasis may prove extremely valuable in directing attention to an early lesion. In the presence of mediastinal enlargement, careful examination of the superficial lymphatics may reveal an enlarged node which by biopsy may indicate the diagnosis.

LABORATORY EXAMINATION

Studies of bronchial secretions stained with the Papanicolaou stain[5] indicate that a high percentage of pathologic diagnoses of bronchogenic cancer can be made by those trained in this technique. For example, Clerf and Herbut[6] were able to make a positive diagnosis in 82.4 per cent of a series of fifty-seven cases of proved bronchogenic carcinoma in which bronchoscopic biopsy was positive in only 42.1 per cent. The ability to differentiate malignant from nonmalignant cells in such stained smears is difficult to acquire, but with added experience this technique should prove to be a valuable addition to our diagnostic armamentarium.

The laboratory diagnosis of tuberculosis, coccidioidomycosis, histoplasmosis, infectious mononucleosis, and blood dyscrasia is mentioned because such tests may assume an important place in the differential diagnosis. Tests of this type do not exclude tumor since a malignant neoplasm may be associated with any of the conditions noted previously. Negative tests frequently assume considerable importance in excluding these conditions which are frequently mimicked by malignant new growths.

ROENTGEN DIAGNOSIS

As Overholt[20] has said so succinctly, "Surveys find but do not necessarily identify disease." In spite of fluoroscopy, position studies, stereoscopic roentgenograms, Potter-Bucky technique, laminographs, and diagnostic pneumothorax, roentgenography can do little beyond placing the lesion in certain pattern groups and localizing its position. Exceptions are the dermoid cysts containing a dental ridge with teeth, diodrast visualization of the great vessels, and diaphragmatic hernia demonstrated by diagnostic pneumoperitoneum.

Circumscribed Lesions.—Numerous authors have pointed out the potential malignancy of the circumscribed intrapulmonary lesions. Cancer is present frequently enough that every such lesion must be considered malignant until proved otherwise. All lesions belonging to this group are sharply circumscribed, located in the periphery of the lung, globular in form, and entirely without diagnostic characteristics. It is only when another physician has erred that one has the opportunity to study serial roentgenograms to determine growth characteristics. Lesions of this type located near the diaphragm present a special differential diagnostic problem as diaphragmatic hernias containing liver or omentum must also be taken into consideration.

Of our 200 cases, 79 were lesions of the mediastinum, heart, and great vessels. Of the remaining 121 cases, exploration was carried out in 86 for circumscribed lesions. Round tuberculous foci constituted the largest segment of this group and accounted for 37 cases. Intrapulmonary fluid-filled bronchogenic cysts of which there were 13 cases were third in frequency. There were three coccidioidomycotic granulomas. Three diaphragmatic hernias were not diagnosed preoperatively because they contained no hollow viscus and pneumoperitoneum was not carried out. Two liver abscesses produced circumscribed shadows in the region of the right diaphragm. There was 1 echinococcus cyst and 1 arteriovenous aneurysm. Of 30 intrapulmonary malignant tumors diagnosed by operation, 18 were classified as round, circumscribed lesions from the roentgenograms. Of these 18 cases, 4 were adenomas, 1 was a primary pulmonary sarcoma, and 13 were bronchogenic carcinomas. In addition, there was 1 angioendothelioma of the diaphragm and 1 pleural carcinoma which presented smooth circumscribed outlines. From this group of 86 circumscribed lesions there were 20 malignant tumors, or 23 per cent.

Atelectasis.—The "pie-piece" or pyramidal shadow of atelectasis with or without evidence of pulmonary suppuration is typical only of bronchial obstruction which may be caused by cancer, adenoma, foreign body, benign bronchial tumor, tuberculous bronchitis, nonspecific granuloma, cicatricial stenosis, or extrinsic pressure on the bronchus. Bronchograms, in such cases, show the point of bronchial obstruction but not its cause.

In this group there was a total of 35 cases. Of these, 16 were due to nonspecific pneumonitis or benign bronchial stenosis. There were 3 cases of tuberculosis with segmental atelectasis which were not diagnosed preoperatively because the bronchial obstruction prevented recovery of the tubercle bacilli from the sputum. There was 1 case of obstruction of a tertiary bronchus by a benign squamous papilloma. The most significant cause of bronchial obstruction was bronchogenic carcinoma which comprised 11 cases, or 31 per cent.

Mediastinal Tumors.—With the exception of dermoid cysts containing teeth previously mentioned, there is little characteristic of the roentgen appearance of the various types of mediastinal tumors. The position and relationships of the tumor are valuable from a percentage standpoint but cannot identify individual tumors. The smooth outline of a mediastinal cyst or tumor may be confused with a similar outline of a malignant lymphoma or a Boeck's sarcoid. The posteriorly placed circumscribed mass may appear to be a neurofibroma or an esophageal cyst but may in reality be an aberrant thyroid adenoma or a bronchogenic cyst. (See Table III.)

TABLE III. ROENTGEN APPEARANCE
(200 Cases of Exploratory Thoracotomy)

	NUMBER	PER CENT	NUMBER	PER CENT
I. Circumscribed Lesions of Pulmonary Parenchyma			86	43.0
A. Round tuberculous foci	37	43.0		
1. True tuberculoma, 24				
2. Caseous tuberculosis, 11				
3. Tuberculous granuloma, 2				
B. Fluid-filled bronchogenic cyst	13	15.1		
C. Coccidioidomycotic granuloma	3	3.4		
D. Diaphragmatic hernia	3	3.4		
E. Liver abscess	2	2.3		
F. Echinococcus cyst	1	1.2		
G. Arteriovenous aneurysm	1	1.2		
H. Hamartoma	1	1.2		
I. Metastatic sarcoma	1	1.2		
J. Actinomycosis	1	1.2		
K. Asymptomatic empyema	3	3.4		
L. Primary malignancy	20	23.0		
II. Atelectasis			35	17.5
A. Chronic nonspecific pneumonitis	16	45.7		
B. Tuberculosis	3	8.5		
C. Benign squamous papilloma	1	2.8		
D. Amoebic abscess	1	2.8		
E. Actinomycosis	1	2.8		
F. Blastomycosis	1	2.8		
G. Empyema	1	2.8		
H. Bronchogenic carcinoma	11	31.4		
III. Mediastinal Lesions			73	36.5
A. Benign	61	83.5		
B. Malignant	12	16.4		
IV. Heart and Great Vessels			6	3.0
A. Benign	6	100		

BRONCHOSCOPY

The medical literature is replete with reports indicating that bronchogenic carcinoma can be diagnosed bronchoscopically in 70 to 90 per cent of cases at some time during the life of the patient. However, the limitations of bronchoscopy in the diagnosis of the early lesions have not been sufficiently emphasized A recent survey of 100 consecutive cases of cancer of the lung in our hospital, proved by surgical removal of the lesion or autopsy, has shown that the primary lesion was located in the bronchoscopically visible portion of the bronchial tree in 43 per cent of the cases. In 57 of the 100 cases the primary lesions could not have been seen or biopsied by bronchoscopy.

Bronchoscopically proved cases of lung cancer are less frequently resectable than the peripheral lesions. Koletsky[10] has called attention to the fact that the anaplastic epithelioma (small or oat-cell carcinoma) involves the stem bronchus in 70 per cent of the cases and is most readily diagnosed bronchoscopically. There is no record in the medical literature of a cancer of this type being cured by pulmonary resection. Of the squamous-cell carcinomas, Gebauer[10] noted that 49 per cent originate in the upper lobe or small branch bronchi where they are not accessible for biopsy until late. This type is the tumor most favorable for resection. Lindskog[17] recently reported a series of 100 bronchogenic carcinomas of which all but 32 were considered inoperable. Of the 32 patients explored, there were positive bronchoscopic biopsies in only 12 cases, or 37 per cent.

In 12 cases, resection was carried out and of these only 2 had a preoperative bronchoscopic biopsy. In Gebauer's series a positive bronchoscopic biopsy was obtained in only 17 per cent of the resectable cases of bronchogenic carcinoma.

Of the 44 cases of pulmonary carcinoma resected in our hospital during the period of this report it was possible to make a preoperative bronchoscopic diagnosis in 20, or approximately 45 per cent. From these facts we conclude that a positive bronchoscopic diagnosis can be made in less than one-half of the operable cases of lung cancer.

In the so-called bronchial adenomas, Holley[14] reported 38 cases in which all but 6, or approximately 85 per cent, were discovered by bronchoscopic examination.

We have seen 12 cases of this type during the period of this report and were able to diagnose 7 of them bronchoscopically. It would appear that adenomas are more frequent in the stem bronchi and that the bronchoscope is quite efficient for their discovery.

DIAGNOSTIC X-RAY THERAPY

Thoracic physicians and surgeons agree, in general, that the use of diagnostic x-ray therapy for possibly removable intrathoracic neoplasms is distinctly harmful since many malignant tumors do not respond to irradiation and, in those that do improve, the malignant nature of the lesion has been established at a cost of a loss of valuable time. A consistent exception to this policy has been made in those lesions suspected of belonging to the lymphoblastoma group. In the past, a response to a "test dose" of x-ray therapy was considered as sufficient diagnostic proof to call the lesion "malignant lymphoma" with its grave prognostic significance. Exploratory thoracotomy was considered too extensive a procedure to justify a diagnosis by pathology. The risks of thoracic exploration have now decreased so sharply that we are re-examining this subject. It has been our experience that the slight risks involved are far outweighed by the benefits to the patient of a diagnosis based on the histology of the lesion, prompt institution of a proper therapeutic regimen, and an increase in the physician's knowledge of the nature of the lesion.

Histology and X-ray.—When confronted with lymphadenopathy apparently confined to the mediastinum, one must consider various forms of lymphoma: giant follicular lymphoma, reticulum-cell sarcoma, lymphosarcoma, and Hodgkin's disease, as well as the mediastinal cysts and tumors, tuberculosis, histoplasmosis, sarcoidosis, carcinoma, chronic inflammation, infectious mononucleosis, syphilis, leucemia and certain other conditions.

All members of this group are to some degree sensitive to irradiation. The results of irradiation, however, vary within wide and unpredictable limits. This is best illustrated by Hodgkin's disease, in which certain types with a high connective tissue content are almost entirely radioresistant while other types principally lymphocytic in origin respond dramatically to a very small amount of irradiation. Blades[4] has stated that 750 R. constitutes an average test dose but estimates that one-fourth to one-third of cases of malignant lymphoma require as much as 1,500 R. to affect the tumor. We have recently seen a case of proved mediastinal Hodgkin's disease in which the mediastinal tumor continued to increase in size while the patient was getting a full therapeutic dose of x-ray therapy. Response to x-ray irradiation would therefore seem an extremely slender reed upon which to rest a diagnosis with the prognostic significance of any of the lymphoblastoma group.

A favorable response to irradiation is by no means a characteristic limited to the malignant lymphomas. Certain tumors of the thymus, indistinguishable roentgenographically from the lymphoblastoma group, are quite sensitive to x-ray therapy. These tumors may be quite late to metastasize and offer an opportunity for cure if recognized at an early stage and removed by surgery. A response to x-ray in such cases leads not only to an erroneous diagnosis but also may mean the loss of opportunity for complete surgical removal of the lesion.

In sarcoidosis, rapid spontaneous remission may cause large masses of mediastinal nodes to decrease until they are hardly visible. Should such an occurrence coincide with a period of x-ray therapy and thereby inspire a diagnosis of radiosensitive lymphoblastoma, the implications are dangerously evident.

Hazards.—Following therapeutic irradiation, normal cleavage planes are fibrosed and distorted to the point that surgical removal of the lesion is vastly more difficult. This, of course, varies with the amount of therapy given. Since no general agreement has been reached as to what constitutes a "test dose," 2000 R is frequently exceeded. In such instances, attempts at surgical removal of the lesion become distinctly hazardous.

Following x-ray therapy, an accurate histologic diagnosis from stained sections of the lesions is usually not possible because of the cytolytic effect of the irradiation which may have destroyed the characteristic cells on which the diagnosis rests.

Localized Lymphoma.—The diagnosis of any type of lymphadenopathy must rest on a properly executed biopsy. When the mediastinal involvement is part of a generalized disease, a peripheral node may easily be taken for this examination. While it is true that the superficial lymph nodes are sooner or later almost invariably involved, at the beginning the disease develops in the nodes of a single region; then during subsequent exacerbations it spreads to other groups of lymph nodes. This first or localized stage of a malignant lymphoma may originate in any set of nodes, but usually involves an internal group. Symmers[25] stated that primary enlargement of abdominal or of abdominal and thoracic nodes combined is ten times more common than primary enlargement of cervical nodes. Ewing[5] supported this view, adding that the superficial nodes which first attract attention are merely the outlying portions of an internal lesion. During this first stage, the most common site of deep adenopathy is the mediastinum. Enlarged mediastinal nodes are readily demonstrated by routine roentgenograms of the chest and this often offers the opportunity for early diagnosis and institution of therapy. Too frequently this opportunity is lost by procrastination.

THE RISKS OF EXPLORATORY THORACOTOMY

As would be expected, the risk of surgical exploration of the chest is dependent upon the therapeutic portion of the operation. There were no deaths in this series attributable to exploration per se. Eight deaths occurred in the 200 cases reported here as a result of postoperative complications. Of these, 5 were in pneumonectomies performed for cancer, 3 of pulmonary edema and 2 of bronchopleural fistulas. One additional death from pulmonary edema occurred following pneumonectomy for blastomycosis. There was 1 death in the 56 lobectomies reported in this series, this due to bronchopleural fistula. The remaining death was due to massive hemothorax from an inoperable neurogenic sarcoma.

In addition to the postoperative complications noted here, there were 12 pleural effusions requiring from one to three thoracenteses, 5 cases of atelectasis treated by bronchoscopy, 3 minor wound infections, and 4 empyemas.

SUMMARY AND CONCLUSIONS

Mass x-ray surveys have vastly increased the opportunities for early discovery of thoracic lesions, frequently prior to the onset of symptoms. This presents a challenge to thoracic surgeons to make an early diagnosis. The conservative diagnostic measures should be employed as expeditiously as possible, recognizing their limitations, but in obscure cases early thoracic exploration is indicated.

We present 200 cases of exploratory thoracotomy performed for the diagnosis and treatment of obscure intrathoracic disease. In this series of consecutive cases, malignant tumors occurred in 21.5 per cent, or approximately 1 in 5 cases.

The limitations of bronchoscopic diagnosis have been emphasized and evidence presented to show that, in resectable cases, positive bronchoscopic biopsy can be expected in less than 50 per cent of the lesions. Therefore a negative bronchoscopy is of no value in excluding intrathoracic neoplasm.

The accepted practice of using x-ray therapy as an adjunct in the diagnosis of malignant lymphomas is condemned because:

1. All malignant lymphomas do not respond to x-ray therapy.
2. Many benign lymphadenopathies and resectable malignant lesions of the thymus do respond to irradiation and would lead to an erroneous diagnosis.
3. There are indications that the prognosis of localized mediastinal lymphoma is improved by combined resection and irradiation therapy.
4. The prompt establishment of a histologic diagnosis expedites initiation of treatment.

Of the 86 circumscribed parenchymal lesions, 20 were found to be malignant. This emphasizes the necessity of early exploration in undiagnosed lesions of this type. This course is further indicated for the definitive treatment of the circumscribed benign lesions.

Of 35 cases of chronic pulmonary suppurative diseases due to unexplained bronchial obstruction, 31 per cent were found to be caused by bronchogenic carcinoma. Pulmonary resection is the treatment of choice for both benign and malignant chronic pulmonary suppuration.

The risks of exploratory thoracotomy depend on the therapeutic portion of the operation. There was no mortality and minimal morbidity due to thoracic exploration per se.

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DISCUSSION

DR. OSLER ABBOTT, Atlanta, Ga.—I would like to emphasize the role of exploratory thoracotomy in diseases of the cardiovascular system, as well as that which we have heard described in relation to the lung. At our clinic, we have been interested in the atypical character of the physical findings in a certain number of patients having patent ductus arteriosus. We recently reported a study of seven such patients. Their physical findings varied from complete absence of the diastolic component of the murmur, to patients in whom one noted absence of any murmur during certain periods of observation. We feel that in such patients considerable help may be obtained by the additional investigative procedures of angiocardiography and cardiac catheterization.

Inasmuch as one had been led to consider positive angiocardiographic findings to be almost impeccable evidence of patent ductus arteriosus, I would like to present one case in which a very typical angiocardiogram had been obtained. There was enlargement of the pulmonary artery, obliteration of the aortic window, and a saccular dilatation of the aorta in the ductus area. However, upon exploration, we found that the dilatation of the aorta was due to a combination of the aorta being sagittal in position and the aorta below the descending arch being markedly hypoplastic. Furthermore, the pulmonary artery was enlarged, due to poststenotic dilatation. The most surprising finding was a congenital absence of the left half of the pericardium. The pericardium was present on the left side, in the area of its lower third, and was constricting this area of the apex. Therefore, this was resected, and by means of keeping the patient upon the opposite side for a few days, postoperatively, an uneventful recovery occurred. The only change in physical findings following operation has been an absence of change in the character of the murmur with changes of position, which had occurred, preoperatively.

With such experiences as those noted here, there appears to be a definite place for exploratory thoracotomy in the treatment of congenital heart lesions.

CHRONIC NONSPECIFIC SUPPURATIVE PNEUMONITIS

A Report of Ten Cases

Richard D. Kershner, M.D. (by invitation), and W. E. Adams, M.D.
Chicago, Ill.

WITH the increase of surgery for the treatment of inflammatory and malignant lesions of the lungs in the last two decades and the refinement of diagnostic procedures, our knowledge in this field continues to enlarge. This report deals with a group of patients who have been observed and treated for a *nonmalignant condition of the lung to be differentiated from lung abscess, tuberculosis*, bronchiogenic carcinoma, and bronchiectasis. This pulmonary lesion produces symptoms, signs, and pathologic characteristics sufficient for differentiating it as a disease entity. A definite etiological agent has not as yet been determined and the bacteriology is nonspecific.

This condition has been given the name chronic nonspecific suppurative pneumonitis and belongs under the general heading of chronic inflammatory lesions of the lung. In the literature there are a few scattered reports of similar cases, and there are doubtless many more instances which have not been published.[1, 2, 3]

CLINICAL CHARACTERISTICS

There was a predominance of female over male patients in a ratio of about two to one. The age of the patients varied from 30 to 61 years, but most fell in the bracket between 30 and 50 years. The onset was insidious, without a recent history of an acute pneumonic process. The main symptoms were productive cough, hemoptysis, and chest pain. Many had had a productive cough for several years, coming to the doctor only when blood had appeared in the sputum. These symptoms varied in duration from three months to twenty-two years, most patients having had them for over four years. Only two patients had not experienced hemoptysis at least once and in some this was a prominent symptom. About one-half of the patients had experienced chest pain. Usually this had been present for only a few months before the patient entered the hospital. (See Table I).

Unlike patients with chronic lung abscess or bronchiectasis, this group of patients showed little evidence of weight loss and did not appear chronically ill. There was usually no evidence of sinusitis or clubbing of the fingers. The positive findings were usually confined to the chest, which revealed dullness over the involved lung areas with dry coarse râles being present in about one-half the cases.

In five patients there was a temperature elevation of 99° to 101° F. at the time of admission, and in one case this had been known to exist for more than a year. The past history and family history were noncontributory in all cases.

From the Department of Surgery of the University of Chicago.

Read at the Twenty-Seventh Annual Meeting of the American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

TABLE I. CLINICAL CHARACTERISTICS IN TEN CASES OF CHRONIC NONSPECIFIC SUPPURATIVE PNEUMONITIS

SYMPTOMS		DURATION		AGE	
Cough	10	6 mo.	1	31-40	5
Hemoptysis	8	2-4 yr.	4	41-50	4
Chest pain	5	6 yr.	2	51-60	1
Temperature 99° to 101° F.	5	10 yr.	1		
		16 yr.	1		
		22 yr.	1		

Repeated sputum examinations were negative for tubercle bacilli in every instance, and a definite etiological agent was not determined since the bacteriology was nonspecific. Blood and urine examinations were essentially normal. In three patents, there was a leucocytosis of approximately 12,000. The albumin-globulin ratio in the three cases in which it was determined varied between 0.84 and 0.94.

X-rays of the chest showed diffuse infiltration of various lung areas in all cases and a suggestion of atelectasis in four of the ten cases. In five patients, areas of infiltration in more than one lobe could be seen by x-ray. There was no identifiable abscess in any case. In seven of the ten cases, the lesions were on the right side, and in one case the lesion was bilateral. Differential diagnoses by x-ray varied with the findings but included hilar tuberculosis, lung abscess, neoplasm of the bronchus or mediastinum, pleural effusion, and bronchiectasis. Bronchograms made in some cases showed blunting of the bronchi but no evidence of dilatation.

Bronchoscopic examination revealed inflammation of the bronchial mucosa and pus formation in the bronchi of the lobes involved by the lesion in eight of the ten patients. The findings were entirely normal in one case, and a biopsy made elsewhere was reported positive for tumor in another case.

DIFFERENTIAL DIAGNOSIS

Chronic, nonspecific, suppurative pneumonitis is to be differentiated from bronchiogenic carcinoma, benign tumors of the lung and mediastinum, lung abscess, tuberculosis, and bronchiectasis. Bronchoscopy aids in differentiating bronchiogenic carcinoma, but many carcinomatous lesions are in the periphery or in the upper lobes and cannot be visualized by bronchoscopy. In some cases, the final diagnosis must await the findings of surgical exploration and microscopic examination of the tissue.

The insidious onset and chronic course, along with the absence of an etiological factor for production of a lung abscess, are helpful in differentiating chronic nonspecific suppurative pneumonitis from either lung abscess or bronchiectasis. Furthermore, the age of these patients was considerably advanced over that which is usual for patients with bronchiectasis, and their cough was much less productive. In addition, bronchograms showed blunting of the bronchi rather than a dilatation as seen in bronchiectasis. The absence of a cavity with a fluid level in the x-rays was suggestive of pneumonitis rather than a lung abscess. The absence of tubercle bacilli in the sputum and the location of the lesion in the lower or midlung field were against the likelihood of tuberculosis but did not exclude this diagnosis.

With a realization of the existence of the condition and its characteristic findings, later cases in this series were diagnosed from the history, bronchoscopy, and x-ray findings alone. In the ten cases presented below, the preoperative diagnosis was carcinoma of the lung in three, bronchiectasis in one, tumor or infection of the mediastinum in one, and chronic, nonspecific, suppurative pneumonitis in five.

TREATMENT

Under medical management consisting of postural drainage, bronchoscopic aspiration, bed rest, expectorants, and, in the more recent cases, the sulfa drugs, many of the patients showed a transcient period of improvement, but after variable periods of remission, symptoms would recur and a progression of the lesion could be seen by x-ray and bronchoscopy. Most of the patients became ill enough that they were forced to give up their occupations and became discouraged with the ineffectiveness of medical management.

Surgery by drainage or resection was used in nine of the ten cases presented, and was followed by complete recovery in all instances except one, that patient dying of pneumonia five days after operation. The patients became able to take part in a normal full day of activity within a year after the operation.

The earlier patients in this series of cases were treated by drainage through the chest wall. Because of the necessity of multiple operations and a longer period of morbidity by this method, subsequent patients have been treated by *lobectomy or pneumonectomy as the procedure of choice. In deciding whether* to treat by drainage or resection, the age and physical condition of the patient, and location of the inflammatory process were considered.

In five cases, the patients were treated by lobectomy, in two by pneumonectomy, in two by thoracotomies and open drainage. In the bilateral case, a biopsy only was made. In the five patients treated by lobectomy, the lesions were mainly in the right middle lobe in two, the left lower lobe in two, and the right lower lobe in the fifth. In two of these five cases, there was evidence of involvement of the other lobes on the same side by x-ray examination, and palpable lesions were felt in these areas at the time of surgery. In the two cases treated by pneumonectomy, the preoperative diagnosis was carcinoma of the lung, and the pathologists were unable to say definitely that biopsy sections made at the time of operation were not neoplastic. In these patients, in view of the history and x-ray findings, it was decided to completely remove the involved lung. One thoracotomy and drainage was done for a lesion in the right middle lobe, and the other was for a lesion in the right lower lobe.

All the patients except one, whether treated by resection or drainage, became symptom-free and able to partake of a full program of activity within one to two years after surgery. In the group of seven resections, there was one death occurring five days following operation. The condition of the patient with bilateral lesions was essentially unchanged when last seen. Her chest symptoms had always been minimal, her chief difficulty being arthritis. The lung pathology had been found during a routine x-ray examination.

With resection the patients' stay in the hospital averaged twenty-two days, and clearing of the remaining lung fields occurred on an average of six to seven months. With drainage, the patients remained in the hospital an average of fifty-nine days, and clearing of the lung fields required about twelve months. Also, more inconveniences and visits to the out-patient department were required for the patients having had treatment by drainage. In the two cases treated by drainage, the patients both had a minimal bronchitis two years later and seemed more susceptible to "colds" and bronchopneumonia than the patients treated by resection. Only one of the latter group had a significant productive cough and sputum remaining one year after operation. The differential diagnosis, therapy, and results are summarized in Table II.

TABLE II. DIFFERENTIAL DIAGNOSIS AND THERAPY IN TEN CASES OF CHRONIC NONSPECIFIC SUPPURATIVE PNEUMONITIS

PATIENT AND AGE	DIFFERENTIAL DIAGNOSIS	THERAPY	RESULTS
M. K. 47 yr.	1. Chronic inflammation 2. Tuberculosis 3. Carcinoma	Exploratory thoracotomy with three stages of drainage	Lung fields clear except for residual pleural scar; slight productive cough
L. G. 32 yr.	1. Chronic inflammation 2. Tumor 3. Hilar tuberculosis	Exploratory thoracotomy with two stages of drainage	Slight residual clouding in middle of right lung field; had minimal chronic bronchitis two years later
G. N. 38 yr.	1. Tumor 2. Tuberculosis 3. Chronic pneumonitis	Biopsy	Condition essentially unchanged when last examined
C. W. 49 yr.	1. Chronic inflammation 2. Bronchiectasis 3. Chronic granuloma	Right middle lobectomy	Rapid recovery with return to full activity in six months; no residual cough or sputum
E. S. 30 yr.	1. Bronchial adenoma 2. Chronic inflammation 3. Inactive apical tuberculosis	Right middle lobectomy	Lung fields entirely cleared; has occasional productive cough
G. H. 39 yr.	1. Chronic nontuberculosis inflammation 2. Abscess	Right lower lobectomy	Lung fields became clear to fluoroscopy following operation; no residual cough or sputum
H. M. 38 yr.	1. Bronchiectasis 2. Chronic pneumonitis	Left lower lobectomy	Chest became clear by fluoroscopy; no residual cough or sputum
A. R. 44 yr.	1. Chronic pneumonitis 2. Tuberculosis	Left lower lobectomy	Slight hemoptysis for two months postoperative; chest clear by fluoroscopy; no cough or sputum seven months after operation
O. S. 61 yr.	1. Bronchiogenic carcinoma	Right pneumonectomy	Died five days after operation with hemorrhagic bronchopneumonia and pericarditis
A. C. 44 yr.	1. Bronchiogenic carcinoma	Right pneumonectomy	Remaining lung field clear by fluoroscopy; no residual cough or sputum

PATHOLOGY

The histopathologic findings in the present series are summarized in Table III. Grossly the involved lung tissue was, in most cases, infiltrated and atelectatic. Hard nodules were palpated in the lesions in two of the cases and small necrotic areas were found on sectioning in four cases.

TABLE III. SYMPTOMS AND HISTOPATHOLOGY IN TEN CASES OF CHRONIC NONSPECIFIC SUPPURATIVE PNEUMONITIS

CASE	COUGH	HEMOPTYSIS	DURATION IN YEARS	AGE	LOCATION OF LESION	FIBROSIS INTERLOBULAR	THICKENED FIBROSED ALVEOLAR WALLS	LYMPHOID HYPERPLASIA	BRONCHIAL LUMEN NARROWED	CHRONIC ATELECTASIS	HYALIN IZATION	PLASMA CELL INFILTRATION	MACROPHAGES	SQUAMOUS EPITHELIUM	BIOPSY	RESECTION	DRAIN
1 M. K.	X	X	2	47	Right lower lobe	X	X	X	—	—	—	—	X	—	X	—	X
2 L. G.	X	X	½	32	Right upper middle, lower lobes	Microscopic section insufficient for pathologic study					—	—	X	—	X	—	X
3 G. N.	X	X	16	38	Bilateral in lower lobes and also right middle lobe	X	X	X	—	—	X	—	X	—	X	—	—
4 C. W.	X	X	10	49	Right middle lobe	X	X	X	X	X	—	—	X	—	—	X	—
5 E. S.	X	X	6	30	Right upper, middle and lower lobe	X	X			X	—	X	X	—	—	X	—
6 G. H.	X	X	4½	30	Right lower lobe	X	X	X	X	X	—	X	X	X	—	X	—
7 H. M.	X	—	22	38	Left lower lobe	X	X	XXX	XX	X	—	—	X	—	—	X	—
8 A. R.	X	X	6	44	Left lower lobe	X	X	X	X	X	—	—	X	—	—	X	—
9 O. S.	X	—	3	61	Right upper lobe	X	X	X	X	X	—	—	X	—	—	X	—
10 A. C.	X	X	4	44	Right middle lower lobes	X	X	X	X	X	—	—	X	—	—	X	—
Total	10	8				9	9	9	7	7	1	2	10	1	3	7	2

TABLE IV. BACTERIOLOGICAL FINDINGS IN TEN CASES OF CHRONIC NONSPECIFIC SUPPURATIVE PNEUMONITIS

SPUTUM AND LUNG ASPIRATION	M. K.	L. G.	G. N.*	C. W.	E. S.	G. H.	H. M.	A. R.†	O. S.	A. C.
Hemolytic streptococcus	+	slight +		+	–	–	–	–	–	+
Nonhemolytic streptococcus	–	+		–	+	–	–	–	–	–
Strep. viridans	–	+		+	+	+	+	–	+	+
Staph. albus	+	–		–	+	–	–	–	+	–
Hemolytic *Staph. albus*	+	–		–	–	–	–	–	–	–
Staph. aureus	–	–		–	–	+	–	–	–	–
Staph. aureus hemolytic	+	–		–	–	–	–	–	–	–
Nonhemolytic staphylococcus	–	–		–	+	–	–	–	–	–
N. catarrhalis	–	–		+	–	–	–	–	+	+
Diphtheroids	+	+		+	–	–	–	–	–	–
Small gram (–) rods	+	–		+	–	–	+	–	+	–
Acid-fast	– (guinea pig)	–	–	–	–	–	–	–	–	– (guinea pig)
B. coli	–	+		–	–	–	–	–	–	–
Pneumococcus	–	+		–	–	–	–	–	–	–
Fusiform bacilli	–	+		–	–	–	–	–	–	–
Spra Typhoid Paratyphoid Brucella Agglutinations	–	–	–	–	–	–	Blood Wassermann positive	–	–	–
Friedländer bacillus	–	–		–	–	–	+	–	–	–
Fungus	0‡	– sab		0	– sab	– sab	0	0	– sab	0

*No anaerobic or aerobic growth from biopsy. Direct smear showed (+) cocci and rods and gram-negative organisms. Guinea pig negative for TBC and fungus from tissue culture negative.

†Mostly hemorrhage.

‡0 Indicates cultures were not made.

In general, the histologic picture showed extensive interlobular fibrosis and also fibrosis and thickening of the alveolar walls. There was considerable lymphoid and plasma cell hyperplasia, and the bronchial lumina were somewhat narrowed by the redundant mucosa. Chronic atelectasis was present, blood being found in the alveoli. Many blood vessels presented markedly thickened walls. Hyalinization was present in only one case and squamous metaplasia of the bronchi in only one instance. Some alveoli were lined by bronchiolar epithelium. No bronchial dilatation, acute inflammation, or evidence of walling off as in an abscess were seen. The histopathologic diagnosis was chronic diffuse pneumonitis. This frequently is the only means of differentiating this lesion from bronchiectasis, tumor, and lung abscess.

Aerobic and anaerobic cultures of pus obtained from the bronchi by bronchoscopy and from the tissue removed at the time of surgery showed a nonspecific type of bacteriology. Cultures made for fungus were also negative. Agglutinations for brucella, typhoid, and paratyphoid were also within the normal range in the four patients examined. No virus studies were made. The bacteriologic findings are summarized in Table IV.

Two of the ten cases are being reported in detail to bring out most of the clinicopathologic characteristics and to describe the two methods of management.

CASE 1.—A 44-year-old white man, A. C., came to the clinic with the complaints of hemoptysis for four days, foul sputum averaging about one cup a day for four months, cough of four years' duration, and a weight loss of thirty pounds during the preceding four months.

The patient stated that four months previously he had a sudden onset of weakness one morning accompanied by a cough with the production of foul-smelling sputum and a fever of 103° F., nausea and vomiting, and pain in the chest on coughing. He was treated for lung abscess by his physician and was forced to give up his job as a crane operator. X-rays taken at that time were said to be suggestive of lung abscess. During this period he had a weight loss of 40 pounds. After six weeks, he was able to return to work, had gained ten pounds but still continued to cough and produce a foul-smelling sputum and had a slight elevation of his temperature. Four days before coming here, his sputum began to be tinged with both old and fresh blood and occasionally clots were seen.

He said that he had no severe upper respiratory infection since two years ago when he was treated for pleurisy. He stated that he had pneumonia when 24 years of age. There was no history of tuberculosis in the family.

Physical examination revealed a well-developed and well-nourished man who did not appear acutely ill. The positive physical findings were limited entirely to the chest. There was dullness to percussion over the chest down to the fourth interspace, both anteriorly and posteriorly. Tactile and vocal fremitus were both reduced over this area. A few course râles were heard over the right upper chest. The remainder of the chest was normal. The cardiac dullness and and heart tones were within normal limits. There was minimal clubbing of the fingers, and the gingiva were coated and inflamed.

The laboratory findings demonstrated a normal red cell count and hemoglobin. The white cell count was about 5,000. X-ray and fluoroscopic examination of the chest showed a well-demarcated, infiltrative lesion occupying the middle third of the right lung. There was no evidence of encapsulation or a fluid level. Bronchoscopy showed an inflamed bronchial epithelium on the right side and obliteration of the right upper lobe bronchus by gross swelling of the mucosa. Thick, foul pus rolled out of the right upper bronchus with coughing. The sputum was negative for tubercle bacilli.

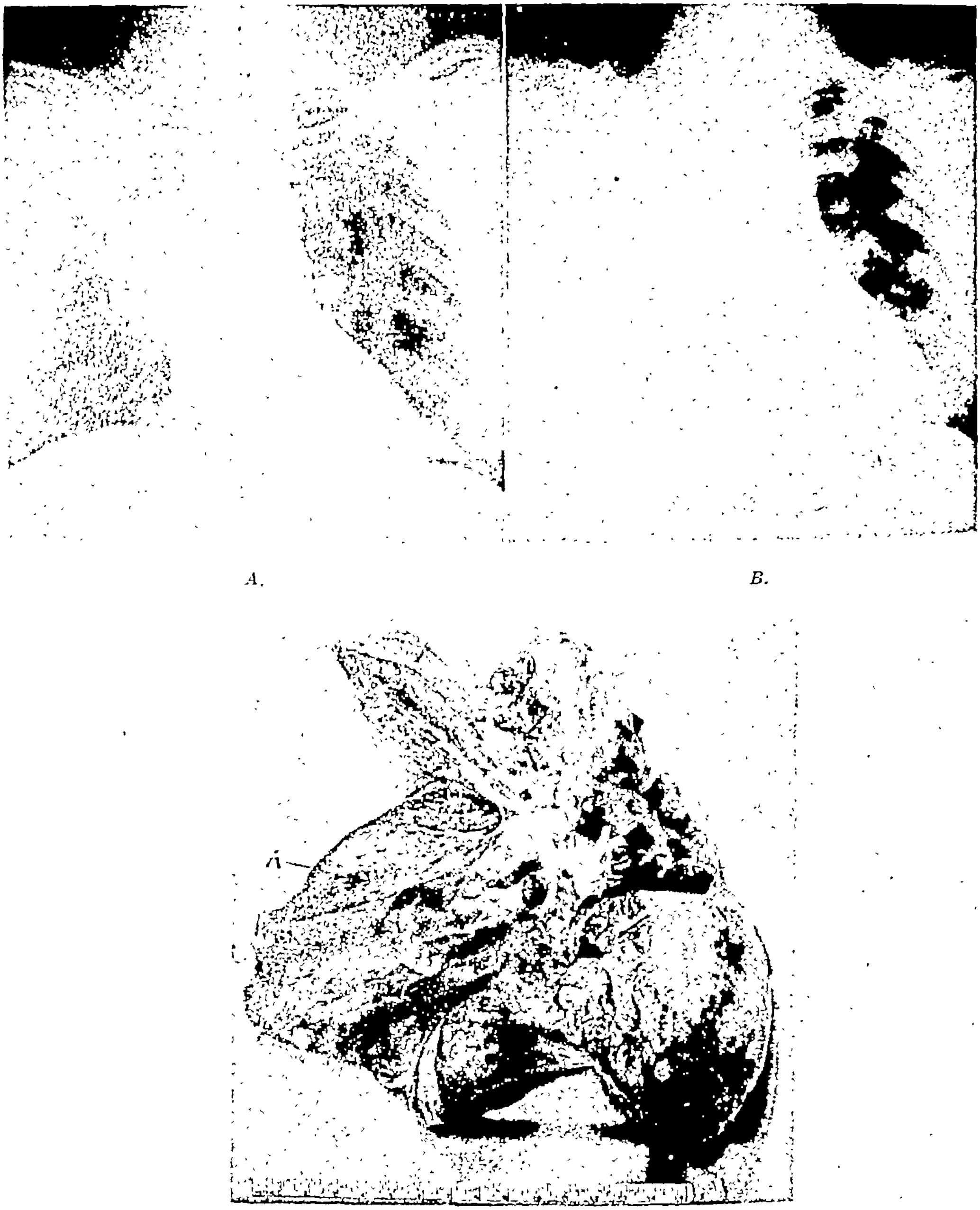
The diagnosis, made on the basis of x-ray, fluoroscopic, and bronchoscopic findings, in addition to the history of rather an acute onset of most of the symptoms, was carcinoma of the lung with large lymph nodes below the carina. (See Fig. 1, *A*.)

The patient was advised to have a right pneumonectomy. The blood picture and plasma protein level of 7.77 being within normal limits, on admission, there was little preparation needed for operation.

Operation.—The operation was performed under ethylene plus ether plus oxygen. Intravenous saline, 1,000 c.c. and 1,200 c.c. of blood were given during the operation. On Nov. 16, 1944, a right pneumonectomy was done, an incision being made over the sixth rib area. The lung was markedly adherent to the chest wall throughout, sharp dissection being necessary to free it. After the lung was freed, a large hardened area was felt in the region of the bronchus approximately 3 cm. by 2 cm. The phrenic nerve was crushed and the pulmonary artery and veins isolated. There was a small node in the mediastinum which was removed and the pathologists could not say definitely whether this showed hyperplasia or neoplastic tissue. Two hard nodes were also palpated below the carina and were removed, thus exposing the left bronchus. A hard node superior to the carina was also removed. After removal of the lung, and before closing the wound, 500 c.c. of plasma and 200,000 units of penicillin were placed in the pleural space.

Surgical Pathology.—The specimen consisted of the entire right lung. The pleural surface over all the lobes was grossly thickened. There was a small hard nodule 0.5 cm. in diameter in the anterior aspect of the lower lobe, which was otherwise normal in consistency. The upper portion of the middle lobe was hard and diffusely infiltrated. The upper lobe was firm and dense in consistency and on section a small cavity was found in the apex communicating directly with the main bronchus of the lobe. The cavity and bronchus contained purulent exudate. The hilar nodes were enlarged and firm in consistency.

Microscopic sections showed interlobular fibrosis and considerable thickening of the alveolar walls. There was more exudate than blood in the alveoli, which also contained many macrophages. In some areas the thickened alveolar walls were lined with bronchiolar epithelium. Lymphoid hyperplasia was extensive and squamous metaplasia of the bronchial epithelium was present in some areas. The bronchial lumina were somewhat decreased in size by the muscularis mucosa being in folds due to lymphoid and plasma cell hyperplasia.



A. *B.*

C.

Fig. 1.—*A*, A. C. X-ray of chest showing an ill-defined infiltrating lesion occupying the upper two-thirds of the right lung. X-ray diagnosis, bronchiogenic carcinoma. *B*, X-ray of chest following total right pneumonectomy. The right pleural cavity has been completely filled with fluid. *C*, Photograph of right lung showing upper lobe sectioned. This revealed diffuse infiltration with a small area of liquefaction seen at *A*. There was no evidence of abscess formation.

Bacteriology.—Cultures showed *Streptococcus viridans, Neisseria catarrhalis* and hemolytic streptococci. Guinea pig inoculations were negative for tuberculosis.

Postoperative Course.—There were no respiratory difficulties or other complications, and the patient was discharged from the hospital three weeks after the operation. The patient's convalescence was uneventful, the temperature remaining below 100° F., except on two occasions when it reached 101° F. When seen about six months after the operation, fluoroscopy of the chest showed the left lung field to be clear, and except at periods during occasional colds, the patient was free from cough and sputum. He began working full time about a year after the operation.

During the next year and one-half, the patient was well except for a mild unproductive cough. Following this period, he became feverish and began to feel weak. Five days later, he noticed a progressive enlargement in the right chest wall which became hyperemic and tender. Ten days after the onset of symptoms, he was seen in the out-patient department and admitted to the hospital.

Physical examination was essentially normal except for the chest. The right side of the chest was dull to percussion and distant bronchial breathing was heard on auscultation. In the anterior axillary line about three fingerbreadths below the axilla there was a large hemispheric tumor about 10 cm. across. The lowermost portion of this mass was tender and slightly fluctuant.

The urine and blood examinations were normal, the leucocyte count being 10,950. The diagnosis was empyema necessitatus. X-rays of the chest at this time showed only the postoperative appearance of a pneumonectomy on the right side and a normal lung on the left side. On July 12, 1946, the abscess was incised and about a liter of foul-smelling yellowish pus was removed. Exploration of the wound revealed a fistulous tract entering the chest cavity through the third interspace. Drains were placed in the chest and in the subcutaneous abscess. After a short period of convalescence the pleural space was obliterated by a two-stage thoracoplasty. The patient made a satisfactory recovery and has returned to full-time employment.

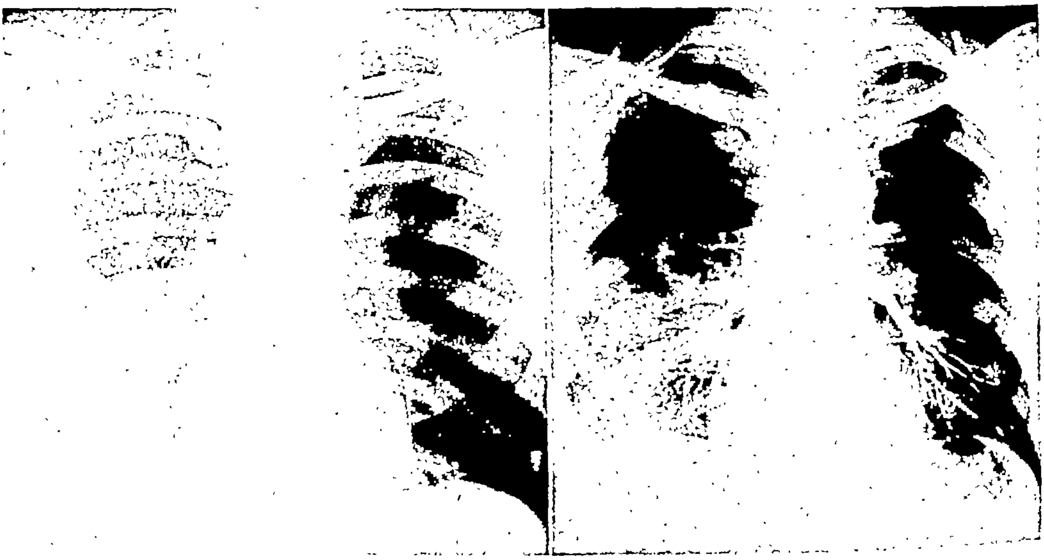
Comment.—This patient illustrates the difficulty of differentiating chronic, nonspecific, suppurative pneumonitis from bronchiogenic carcinoma. The rather acute exacerbation of the symptoms combined with the physical and x-ray findings led to the preoperative diagnosis of tumor, although nothing could be seen or found by bronchoscopy and biopsy. The final diagnosis had to await microscopic examination which showed a rather typical histologic picture of the disease being discussed.

CASE 2.—A 47-year-old truck driver, M. K., was first seen at the clinic with complaints of a productive cough and weakness for two years, a 25-pound weight loss and occasional night sweats for two months. The patient said that he "caught cold" about a year previously and following this had a productive cough and weakness and had lost weight. Following this illness, he was apparently fairly well until about four months previously when he had another illness similar to the one above, but this time the cough and sputum persisted. Two months previously he had been confined to bed for two weeks with what his physician termed a "mild case of pneumonia." There was no hemoptysis. At this time, he began to have night sweats. The sputum had become foul smelling in the past two months and had increased to a cupful a day. He had not worked for five months. The remainder of the history was noncontributory.

Physical examination revealed a well-developed, fairly well-nourished man who did not appear acutely ill but had occasional episodes of coughing. The positive findings were limited entirely to the chest. The left side of the chest and left lung were normal. On the right side there was definite limitation of movement of the diaphragm and dullness to percussion below the sixth thoracic interspace posteriorly, extending around to about the anterior axillary line. Fine crepitant râles were heard over the area on inspiration.

Tactile and vocal fremitus were equal on both sides and there was diminution of breath sounds over the area of dullness. The cardiac dullness and heart tones were within normal limits.

The patient was admitted immediately to the hospital on the medical service for further study. Laboratory findings at that time demonstrated a normal red cell count and hemoglobin with a white count of 9,300. The urine was normal. X-ray examination of the chest at that time revealed a slight elevation of the right leaf of the diaphragm and filling of the costophrenic angle on this side. The left lung was normal. The upper half of the right lung was clear; the lower half was involved by definite infiltrative lesions which extended from the lower portion of the hilum, especially in the area of the seventh rib posteriorly, downward and laterally in the area of the eighth and ninth ribs. A portion of the right lower lobe appeared atelectatic. No abscess cavity was seen. Bronchograms showed narrowing at the bifurcation of the bronchus to the lower lobe. (See Fig. 2, *A* and *B*.) There was no evidence of bronchial dilatation. Bronchoscopy was normal except in the area of the right lower lobe where the bronchial mucosa of that lobe was thickened and injected and contained a small amount of blood-tinged sputum. Just above the point of division, the main bronchial lumen was distinctly narrowed but was still circular in shape. No granulations or tumor masses were seen. The diagnosis of chronic inflammation or bronchiogenic carcinoma was entertained at this time on the basis of x-ray and bronchoscopic findings. A biopsy of the inflamed bronchial mucosa made a week later revealed only a mild degree of inflammatory reaction but no tumor cells or ulceration. No definite diagnosis was made, and the patient was discharged from the hospital four days after admission to be followed in the out-patient department.



A. *B.*

Fig. 2, *A* and *B*.—*A*, M. K. X-ray of chest showing a poorly defined infiltrating lesion occupying the lower third of the right chest. *B*, X-ray showing iodized oil injection of the lower lobes. Note poor filling in right lower lobe region with blunting of secondary bronchi. There is no evidence of bronchiectasis or lung abscess.

He again entered the hospital five months later. During the intervening period, he had been fluoroscoped and had a second x-ray examination which showed the lung lesion to be essentially unchanged. During the interim, the patient had gained a little weight, and said that his cough had become less severe. He had been able to return to work. About one month before the second admission, he began to raise more sputum and enlargement of the lesions in the lung was noted on fluoroscopy. He again began to lose weight. Bronchoscopy showed an increase in the inflammation of the bronchial mucosa, but biopsy again revealed no evidence of malignancy. Due to the negative bronchoscopic findings and the chronic course, it was felt that the patient had a chronic, slowly progressing pulmonary suppurative disease and he was again admitted to the hospital. At the time of the second admission, he was coughing almost continuously and appeared somewhat emaciated.

Physical findings at this time were essentially the same as before. The sputum was seen to contain blood. Laboratory findings showed a normal urine, red cell count, and hemoglobin. The white cell count was 13,000.

X-ray examination revealed the lesions to be essentially unchanged. Sinus x-rays taken at this time were normal. Bronchoscopy showed large quantities of pus coming from the right bronchi with a red and thickened mucosa, and some constriction of the secondary bronchi was seen.

In view of the consistently negative findings for tumor and the long chronic course and sputum examinations negative for tubercle bacilli, a diagnosis of chronic pulmonary suppuration was made. Postural drainage and potassium iodide were ineffective and the patient was prepared for surgery.

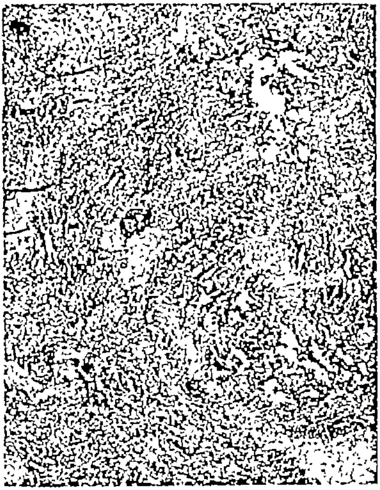


Fig. 20.—M. K. Low-power microscopic section of tissue removed from lower lobe showing marked interlobular fibrosis and lymphoid hyperplasia.

Operation.—A two-stage drainage under ethylene-oxygen anesthesia was planned, the first stage being done on Feb. 21, 1939. An incision was made through the eighth rib area. Dense, vascular adhesions were encountered and were dissected superiorly to about the level of the sixth interspace. The lung was everywhere bound by similar pleural adhesions. On palpation, the lung was firm, somewhat irregular in consistency, and apparently apneumatic. Because of the vascular adhesions and indurated consistency of the lung tissue, further operative procedure was considered inadvisable. An area in the posterior axillary line was packed with gauze and the wound was closed.

Three days later the second stage was done under local anesthesia. The middle of the previous wound was reopened and the packs removed. An aspirating needle was introduced into the region suggested by the x-rays as being involved, but no frank pus was obtained. The lung was then divided by cautery, a piece 1.5 by 1 cm. being removed for microscopic study. The lung was then explored by an aspirating needle in the depths of this area. Actual

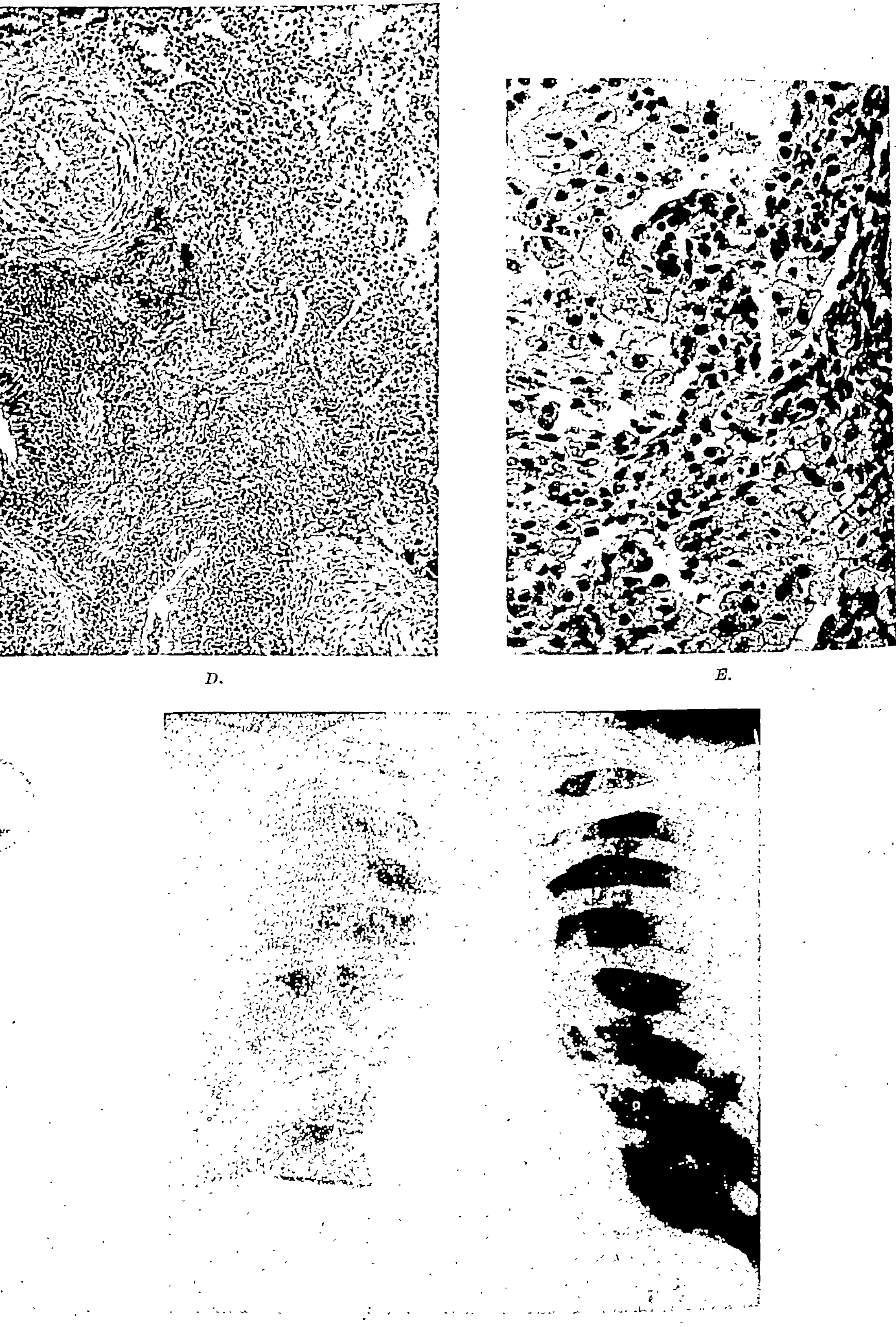


Fig. 2, *D*, *E*, and *F*.—*D* and *E*, M. K. High power photomicrographs of the lung showing thickened, fibrosed alveolar walls, plasma cell infiltration, thickening of blood vessel walls, and many fat-filled macrophages. *F*, X-ray of chest showing complete healing of lesion in right lower lobe. Only mild fibrosis and some tenting adhesions at midportion of the diaphragm remained.

cautery was then used to expose the area for drainage. The tissues in this region were friable and the septae were broken with the finger tip. Little egress or ingress of air was noted. No frank pus was found. The tissues were curetted for microscopic section, and the entire space was packed open with a petrolatum gauze roll.

Postoperatively, there was profuse serous drainage from the wound. Three weeks later, the wound was enlarged under local anesthesia. With the Bovie coagulation, the incision in the lung tissue was extended superiorly and medially. A definite abscess cavity was not encountered. There was a moderate amount of pus and necrotic material in this area. A block of lung tissue measuring about 3 by 2 by 2 cm. was removed for microscopic study. No evidence of sacculation was demonstrable and no tissue resembling tumor was encountered. The wound was packed open. There was no gross evidence of bronchial fistulae.

Surgical Pathology.—The microscopic sections of lung tissue showed interlobular fibrosis and thickened alveolar walls with lymphoid hyperplasia and some chronic interstitial inflammation.

Bacteriology.—Diphtheroids, small gram-negative rods, hemolytic streptococci, *Staphylococcus albus*, hemolytic *Staph. albus* and *aureus* were found in the cultures. Guinea pig innoculations were negative for tuberculosis.

Postoperative Course.—The patient had a very uneventful convalescence, the temperature being over 100° F. on only one occasion following the third stage. Drainage from the wound was profuse at first, but by the time of the patient's discharge, a small tube was being used and drainage was minimal. The patient was discharged two and one-half weeks after the operation and returned to the out-clinic for change of dressings. X-rays taken two months after the final operation showed a decrease in the size of the density in the right lower lung. The wound was completely healed six months after surgery and x-rays at that time showed only mild fibrosis remaining in the middle of the right lower lung field and tenting adhesions at the midportion of the right leaf of the diaphragm. (Fig. 2, *F.*) The patient returned to work about this time and had only a slight productive cough upon arising in the morning, the temperature being normal. He has been seen at infrequent intervals and has remained well.

Comment.—The difficulty in differentiating this lesion from bronchiogenic carcinoma and lung abscess is shown. The final diagnosis was not made until the lung was explored and the surgical specimen examined.

The greater chance for complications and the slower rate of recovery, and correspondingly longer period of hospitalization with treatment by drainage, indicate the advantage of lobectomy and pneumonectomy.

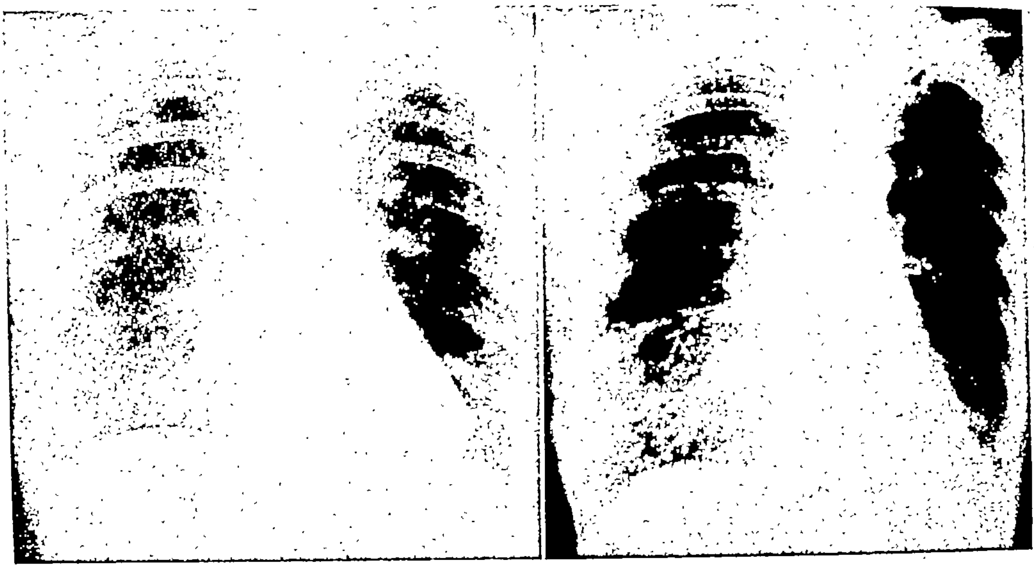
DISCUSSION

In recent years, there has been little written on inflammatory lung conditions per se and most of the articles before 1940 appeared under the heading of chronic nontuberculous pulmonary disease.

Solomon[4] in 1940 reported seventeen cases of chronic infection of the lungs due to the Friedländer bacillus. Most of these cases showed complete clearing of the lung fields eventually, but a few showed some residual fibrosis. Bronchiectasis and abscesses may also develop from this condition. The cases presented by Solomon all had an acute phase just preceding the chronic phase.

The group of cases being reported differ from the above in that there is no acute onset, the patient having had cough and sputum for months or years and gradually being overcome by the lung condition. Also, the lesions tend to progress, and there is no definite etiological factor known, as in Solomon's group.

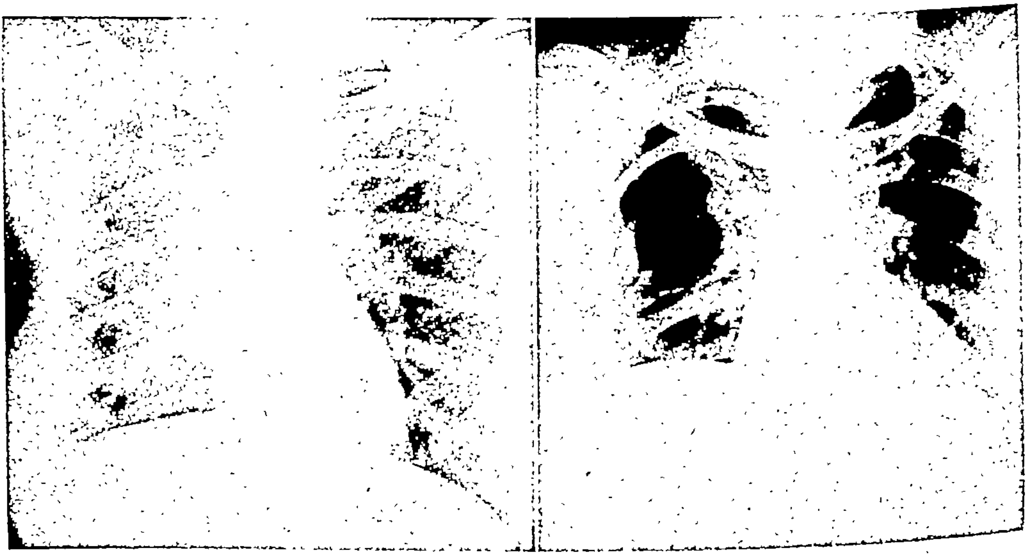
Friedländer and Wolpaw,[1] in an article on the differentiation of bronchiogenic carcinoma from chronic inflammatory lesions of the lung, present four



A. *B.*

Fig. 3.—*A*, C. W. X-ray of chest of a 19-year-old white woman who complained of a productive cough with repeated hemoptyses of ten years' duration. There had been mild pain in the right lower thorax for the preceding few months. Note ill-defined diffuse density at cardiophrenic angle.

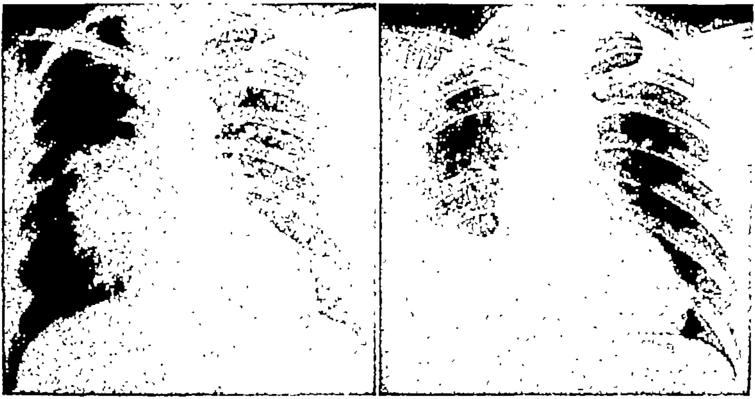
B, X-ray of chest following iodized oil injection. Note poor filling of right lower lobe with some blunting of secondary bronchi. The right lower lobe was resected, after which the patient was completely relieved of symptoms. The specimen removed showed diffuse infiltration of the lung without evidence of abscess or bronchiectasis. Microscopic sections revealed a picture similar to that described in Fig. 2.



A. *B.*

Fig. 4.—*A*, L. G. X-ray of chest of a 32-year-old white woman who complained of a productive cough and hemoptysis of six months' duration. Note diffuse infiltration of right lung extending out from the hilum. Bronchoscopy revealed pus coming from the entire right lung. Exploration showed diffuse infiltrating lesion involving all three lobes. By multiple stages this was drained which resulted in complete relief of symptoms.

B, X-ray of chest showing clearing of the lung following drainage. Microscopic sections revealed pathologic changes similar to those described in Fig. 2.



A. *B*

Fig. 5.—*A*, G. H. X-ray of chest of a 39-year-old white woman who complained of a productive cough and hemoptysis of four and one-half years' duration. Bronchoscopy revealed pus coming from the right lower lobe. *B*, X-ray of chest following resection of the right lower lobe. The lesion consisted of a diffuse infiltration of the upper half of the right lower lobe without evidence of abscess or bronchiectasis. Operation was followed by complete relief of symptoms.

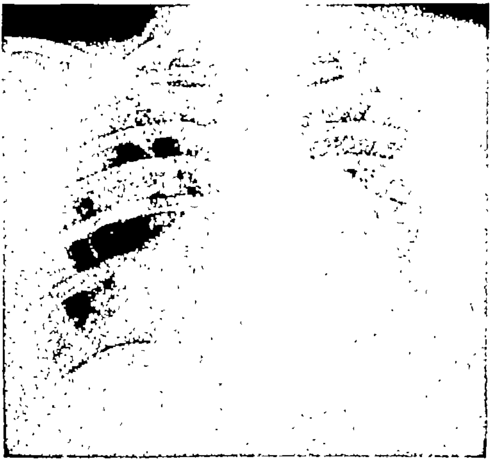


Fig. 6.—G. N. X-ray of chest of a 38-year-old white woman who had symptoms of a mildly productive cough with repeated hemoptysis of sixteen years' duration. Her chief complaint had been multiple arthritis of the knees, ankles, and wrists. Note bilateral infiltrations involving upper and lower lobes. Bronchoscopy and other diagnostic procedures aided little in making the diagnosis. Thoracotomy and biopsy of the lesion in the mid-right lung field showed only diffuse nontuberculous infiltration of the lung with a microscopic picture similar to that described in Fig. 2. The patient's condition remained unchanged when last seen approximately a year following the biopsy.

cases of patients operated for tumors which, histologically, proved to be chronic inflammatory lesions. One of these cases was similar to the ten cases presented below and the inflammation was described as nonspecific in character. No diagnostic method, except awareness of the possibility, was suggested to distinguish the two conditions.

The condition of bronchiectasis is thought by several authorities to develop from suppurative lesions following an acute attack of pneumonia. Hamman,[5] writing concerning nontuberculous basal infections of the lungs, which he thinks are cases of bronchiectasis, gives as characteristic of these cases: (1) cough and expectoration coming on insidiously as a cold or upper respiratory infection; (2) symptoms which persist indefinitely; (3) a moderate, irregular fever; (4) no weight loss, weakness, or exhaustion; (5) usually occurring between the ages of 20 and 40 years; and (6) frequent hemoptysis. X-rays showed only increased pulmonary markings but no definite evidence of pulmonary infiltration, and in all cases the lesions were confined to the lower lobes. One autopsy showed dilatation of the bronchi, and the author assumed this to be present in all the other cases.

The present group differs from Hamman's description of bronchiectasis in the occurrence of weight loss and weakness in addition to a slightly older age group, the earliest age in the cases of this report being 30 years. Also, there is definite evidence of pulmonary infiltration in every instance, and the lesions are not confined to the lower lobes.

According to Sussman[6, 7] "nonputrid pulmonary suppuration differs from simple pneumonia by the occurrence of necrosis of the pulmonary parenchyma." Scadding,[2] writing on "chronic pneumonias," describes most of the cases as resulting from a delayed resolution of an acute pneumonia, or with less acute onset, but with symptoms having been present only a few weeks prior to admission to the hospital. All cases presented were treated without surgery. He defines chronic pneumonias as "a chronic inflammation in which exudation into the pulmonary alveoli is the primary process with organization leading to fibrosis, and suppuration leading to abscess formation, as possible secondary processes, resolution being possible at any stage with more or less residual fibrosis."

The disease entity described in this paper differs from Scadding's chronic pneumonias in, again, the absence of an acute phase, the much longer course, the lack of resolution without surgical treatment, and the lack of progression to abscess formation as a secondary process.

Graham, Singer, and Ballon[8] in their text on surgical diseases of the chest, state that the symptoms of chronic lung abscess may be quite varied and may include cough, blood-stained sputum, fever, chills, sweats, chest pain, weakness, and loss of appetite, in order of frequency. The patients often have a history of repeated respiratory infection. Pathologically, they described lung abscess as "consisting of an irregularly shaped cavity containing thick pus which is often blood-stained. The floor of the cavity is lined with necrotic tissue. Surrounding the abscess is a thick zone of dense fibrous tissue with prolongations of fibrous tissue extending out into the lung in various directions." Some degree of bronchiectasis is stated to be almost always present. A fluid level is necessary for diagnosis by x-ray, other roentgen findings being only suggestive.

In chronic nonspecific pneumonitis the symptoms are chronic and may be quite similar to those of a lung abscess. However, a cavity with a fluid level was not demonstrable on x-ray and the microscopic pathology was unlike that of lung abscess. Bronchiectatic dilatations were absent.

From the standpoint of treatment, the most important conditions to differentiate are bronchiogenic carcinoma and pulmonary tuberculosis. In the case of the former, pneumonectomy is usually the operation of choice whereas a lobectomy may be sufficient in the condition under discussion. In pulmonary tuberculosis, although resection of the lung is indicated in some cases, collapse therapy is more frequently the treatment of choice.

SUMMARY AND CONCLUSION

Ten cases of chronic nontuberculosis inflammation of the lung are reported which present a clinical entity unlike that of lung abscess and bronchiectasis. This disease process is characterized by an insidious onset, chronic course, productive cough and hemoptysis, and a diffuse chronic inflammation of the lung without abscess formation. It must be differentiated from bronchiogenic carcinoma, chronic lung abscess, tuberculosis, and bronchiectasis. The principal features of differential diagnosis are a gradual onset of symptoms without obvious cause, and diffuse infiltration of the lung without bronchial dilatation or cavity formation on x-ray examination. Differentiation of bronchiogenic carcinoma from this lesion in the cases of short duration usually must await pathologic study.

In the ten patients reported, the lesion was resected in seven, drained in two, and biopsied in one. Of the nine patients treated, eight were relieved of symptoms. One patient died five days after resection of the lesion, of bronchial pneumonia of the other lung. Resection of the inflammatory lesion is preferred to drainage, since the period of morbidity is much shorter with the former treatment, and relief of symptoms is likely to be more complete. When bronchiogenic carcinoma cannot be ruled out, this is a further indication for resection of the lesion.

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DISCUSSION

DR. ROBERT M. JANES, Toronto, Ont.—I have been much interested in Dr. Adams' presentation. I am sorry that I did not read the synopsis before coming here, because the cases are very similar, I think, to two that I have operated upon in the last year.

In 1925, Lachlin, in Toronto, working as a relief pathologist at the Children's Hospital, encountered three unusual cases of chronic bronchopneumonia from which children died. The pathologic examination demonstrated that these lungs contained a large amount of fat. Subsequent experimental work showed that this picture could be reproduced by instillation of paraffin oil into rabbits' lungs.

There has been a good deal in the medical and pathologic literature since that time, but surgeons, I think, have perhaps lost sight of it. I know I did, and it seems to me that this is the disease that Dr. Adams has presented to us. At any rate, some of the cases that he has shown seem to be cases of chronic lipoid pneumonia. They go through various stages, from the acute, subacute—in which many of them formerly died of a bronchial pneumonia, although fewer of them are likely to do so now, with the antibiotics—and finally end up with dense fibrosis which is likely to be mistaken for bronchiogenic carcinoma.

The disease is peculiar in that apparently it is possible to have instilled large amounts of oil without the development of lipoid pneumonia. Indeed, it must be because of the frequency with which this has been used, and yet relatively small amounts, it would appear, are capable of producing the disease.

DR. H. BRODIE STEPHENS, San Francisco, Calif.—Dr. Adams is to be congratulated for grouping a type of pulmonary inflammation that all of us have seen but have made no attempt to bring under one clinical classification.

I performed multiple lobectomy recently on the right lung of a patient whose history was much the same as Dr. Janes' patient. The gross and microscopic picture of the original specimen from my patient's lung was similar to those Dr. Adams has demonstrated. We did our best to bring out the history of oil aspiration in this patient but we had to conclude our patient had not used petroleum oil in any form. The patients presented by Dr. Adams certainly resemble cases of lipoid pneumonia and I believe we should continue to make every attempt to prove the diagnosis of lipoid pneumonia before accepting the diagnosis of "chronic nonspecific suppurative pneumonitis."

DR. RALPH B. BETTMAN, Chicago, Ill.—In the first place, I think we should all thank Dr. Adams for giving us a nice new category or pigeonhole in which to place many of the cases that we have all seen and that have been bothering us because we did not know where to put them.

I want to report simply one case to bring out something from the diagnostic and therapeutic point of view.

About four years ago we had a patient at Michael Reese who I am sure, now, would have fallen into this category. The x-ray pictures were so suggestive of a carcinoma of the lung that we decided to go ahead and do a pneumonectomy. However, the patient happened to be a very close relative of the head of our tumor group, and the doctor asked whether we thought it would do any harm if he gave her a course of x-ray treatment first.

We thought the delay would not be very important, inasmuch as the patient had symptoms for a long while. To our great surprise, following the x-ray treatment, the symptoms relieved themselves within two or three days, and the lesion, as far as the x-ray manifestation thereof was concerned, completely melted away in a matter of weeks, and now, four years later, the patient is absolutely well. I think that perhaps the explanation of the efficacious effect of the x-ray treatment can be along the line that Dr. Adams pointed out, when he called attention to the large amount of lymphoid hyperplasia in all these cases.

DR. RICHARD H. MEADE, JR., Chicago, Ill.—I should like to add just three other cases similar to Dr. Adams'.

The first two were chronic in nature. The third patient was operated on the morning after Dr. Adams had talked on this subject in Chicago. This patient had a short history. There was x-ray evidence of atelectasis of the right upper lobe, and although the bronchoscopic examination was negative, we were quite sure that there was a bronchial obstruction due to carcinoma. It has become our habit to look upon such cases almost invariably as carcinoma.

This man had been sick only for two months. He had a history suggesting pneumonia, with some subsidence of symptoms and signs under penicillin therapy.

At operation the upper lobe was found imbedded in the chest by very dense adhesions. When we discovered there was no evidence of tumor, in view of Dr. Adams' paper the night before, we proceeded to do an upper lobe lobectomy. The study of that lobe showed chronic interstitial pneumonitis.

I would think this fitted in well with the group of Dr. Adams' cases, but it was one of very short duration, and I think that gives evidence that this pneumonitic process can develop in a very short period of time.

DR. W. E. ADAMS, Chicago, Ill.—Regarding the question of this being lipoid pneumonia, I do not believe we can say definitely. As Dr. Janes has pointed out, it does not take very much oil to produce that picture. But the microscopic appearance was not like that produced in lipoid pneumonia.

In these cases there was no history of having used oil in the nose, or treatment of upper respiratory infections, but many of the patients had this over such a long period of time that they may not have recalled sufficiently.

Dr. Bettman's question of x-ray therapy is a good one, I think. If this condition is seen early, it might possibly respond to x-ray therapy. Some of our cases were treated by x-ray, but they had had the condition so long that I believe the fibrosis prevented its being effective.

Likewise, I think chemotherapy should be used as a routine, but if response is not immediate, surgery is indicated.

I want to leave this last remark with you, that I feel very strongly that all these cases should be resected, first because so often they cannot be differentiated from bronchiogenic carcinoma. Also, if, at the time of operation, there seems to be a reasonable chance that it is inflammatory rather than malignant, a lobectomy in cases of the older age group might be sufficient, and be the wiser operation to do.

PULMONARY RESECTION FOR CHRONIC ABSCESS OF THE LUNG

ROBERT R. SHAW, M.D., AND DONALD L. PAULSON, M.D. (BY INVITATION)
DALLAS, TEXAS

ABSCESS of the lung has constituted one of the most vexing problems of the thoracic surgeon. Whereas it has long since been proved that medical treatment is ineffective and that this disease is best treated surgically, the ultimate results have not been completely satisfactory. The advent of one-stage surgical drainage, as advocated by Neuhof, represented a definite advance and increased the percentage of satisfactory results of surgical treatment. The increasing safety of pulmonary resection has led to a more frequent application of this procedure in the surgical management of putrid abscess of the lung and has made possible the salvage of a still greater percentage of patients.

Based on statistics available in the literature, it may be stated that the mortality of the disease of putrid abscess of the lung ranges from 30 to 40 per cent. In addition to this high mortality the disease carries a high morbidity. The clinical course is characterized in the chronic phase of the disease by intermittent remissions and exacerbations. During a period of quiescence, the patient continues to cough and expectorate foul sputum, but has very little fever and may be able to carry out his usual activities to a limited degree. During periods of exacerbation of the disease, the patient has high fever, cough with the expectoration of large amounts of foul sputum, and loss of weight. Severe or fatal hemoptysis may occur. Metastatic abscesses to other organs, notably the brain, may develop at any time.

An acute lung abscess is usually unilocular. A chronic abscess of the lung, on the other hand, may become multilocular or be composed of multiple cavities. Bronchiectatic changes in the communicating bronchi frequently occur. Multiple abscesses a few millimeters to a centimeter in diameter may occur as part of a localized chronic pneumonitis occupying a portion of one lobe. The whole lung may be honeycombed by multiple or more or less communicating larger abscesses. The surrounding fibrosis varies greatly in amount and extent. It may simply surround the smaller abscesses, the remaining lung appearing normal. The other extreme is for the entire lung to become fibrotic. The walls of the chronic abscesses are frequently ulcerated and often bleed easily. A rapidly progressive gangrene may develop on the basis of a chronic abscess. Occasionally the walls of a chronic abscess may become completely lined by the proliferation of epithelium from the communicating bronchi. Such an abscess and the communicating dilated bronchi continue to harbor the infection indefinitely.

It becomes apparent from this consideration of the pathology of a chronic putrid abscess in the lung that, in the surgical treatment, drainage alone cannot result in a high percentage of cures. The present report is concerned with the

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From the Division of Surgery, Southwestern Medical College.
Read at the Twenty-Seventh Annual Meeting of the American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

results of the surgical treatment in eighty-six unselected patients having chronic putrid abscess of the lung. As a basis for comparison of the results obtained in this series, we have used the report made by one of us* in 1941 concerning the surgical treatment of putrid abscess of the lung in thirty-three patients. In the former report, surgical drainage was done in all instances. Two patients eventually had pulmonary resection after having been subjected to drainage previously. Nineteen patients, or 57.6 per cent, were considered well following surgical treatment. The mortality was 15.2 per cent.

THE PRESENT SERIES

The present series of cases consists of eighty-six unselected patients treated surgically by us during a three-year period from 1944 to 1947. Six additional patients were seen during this period in whom a putrid abscess of the lung resolved without surgical treatment. All abscesses of a nonputrid type have been excluded from this study.

Ninety-nine surgical procedures were carried out in eighty-six patients. Because the drainage of a putrid abscess of the lung and the drainage of a putrid empyema with a lung abscess represent different problems, these cases were considered separately. Likewise, pulmonary resection for an active abscess presents a different problem from a pulmonary resection for the residual of an abscess, and accordingly these groups were studied separately.

The indications for drainage of an abscess of the lung consisted of an abscess of short duration which was thought to contain a solitary nonepithelialized cavity. In a second group of patients, drainage of the abscess was done as a matter of expediency with the plan in mind of doing a subsequent pulmonary resection. The patients in this group were considered either too acutely ill or in too poor general condition to withstand a primary resection, or it was believed that the extent of the abscess could be diminished by drainage, thereby decreasing the amount of lung tissue to be resection at a subsequent date. The duration of the abscesses in this group varied from one month to twenty-four months, the average being four and one-half months. The ages of these patients ranged from 14 months to 54 years.

Drainage of the abscesses of the lung was done by resection of small segments of one or two ribs as a one-stage procedure in almost all cases. A satisfactory result as judged by disappearance of cough and sputum, and roentgenographic evidence of resolution with no evidence of bronchiectasis or cavity, was obtained in fourteen patients, or 52 per cent of the twenty-seven instances in which drainage was utilized. Nine patients required subsequent pulmonary resection because of the persistence of an abscess following drainage. In five of the nine patients requiring subsequent pulmonary resection, the drainage was done as a matter of expediency and eventual pulmonary resection constituted a feature of the original plan of attack. Three patients obtained an unsatisfactory result from drainage as judged by persistence of cough and sputum or fistula. There was one death due to agranulocytosis following the drainage of an abscess in the right upper lobe.

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TABLE I. PUTRID LUNG ABSCESS
(EIGHTY-SIX UNSELECTED PATIENTS TREATED SURGICALLY)

PROCEDURE	NUMBER	RESULTS			MORTALITY
		SUBSEQUENT RESECTION	SATISFACTORY	UNSATISFACTORY	
Drainage of lung abscess	27	9	14 (52%)	3	1 (3.7%)
Drainage of empyema and lung abscess	12	3	4	5	0
Resection for active lung abscess	52	1	43 (82.7%)	7	2 (3.8%)
Resection for residuals of lung abscess	8	0	8	0	0
Total	99	13	69	15	3 (3.5%)

Drainage of a putrid empyema associated with an abscess of the lung may be considered a procedure of expediency in that further surgery at a later date may be necessary. This procedure was necessary in twelve patients, three of whom had a subsequent pulmonary resection. Drainage of the empyema and abscess led to a satisfactory result in only four of these patients. In five patients the results were considered unsatisfactory as determined by persistence of cough, sputum, residual pulmonary cavity, or bronchiectasis. There were no deaths in this group.

Pulmonary resections for active abscesses of the lung were done in fifty-two patients. Forty-three, or 82.7 per cent, of these patients obtained what was termed a satisfactory result as judged by the absence of cough, sputum, chest pain, and residual empyema. The duration of the abscesses in this group varied from two months to eleven years, the average being fifteen months. The ages of these patients ranged from 18 to 25 years. Two patients died following pulmonary resection, a mortality of 3.8 per cent.

In eight patients pulmonary resections were done for residuals of abscesses. The residuals of an abscess consist of a persistent cavity, bronchiectasis, or a persistent fistula with very little evidence of active infection. All eight patients obtained a satisfactory result, and there were no deaths in this group.

A total of three of eighty-six unselected patients treated surgically died, an over-all mortality of 3.5 per cent.

Pulmonary resections for active abscesses were done as a primary surgical procedure in thirty-five of the eighty-six patients, or 40.7 per cent. The indications for primary resection consisted of an abscess of long duration consisting of multiple or multilocular cavities which were not considered suitable for drainage. The presence of bronchiectasis, in association with an abscess or severe hemoptysis, was considered an indication for primary pulmonary resection. The types of pulmonary resection done for active abscess of the lung together with the results obtained are indicated in Table II.

Segmental resection for abscess was utilized in only three instances. All three patients developed a postoperative empyema. A satisfactory result was obtained in two patients, but the remaining patient continues to have repeated small hemoptyses. There were no deaths in the group of segmental resections.

TABLE II. PULMONARY RESECTIONS FOR ACTIVE PUTRID LUNG ABSCESS

TYPE OF RESECTION	NUMBER	PREVIOUS SURGERY	POST-OPERATIVE EMPYEMA	RESULTS		MORTALITY
				SATISFACTORY	UNSATISFACTORY	
Segmental resection	3	0	3	2	1	0
Lobectomy	35	14 (40%)	9 (25.7%)	29	5	1
Pneumonectomy	14	3 (21.4%)	3 (21.4%)	12	1	1
Total	52	17 (32.7%)	15 (28.8%)	43 (82.7%)	7 (13.5%)	2 (3.8%)

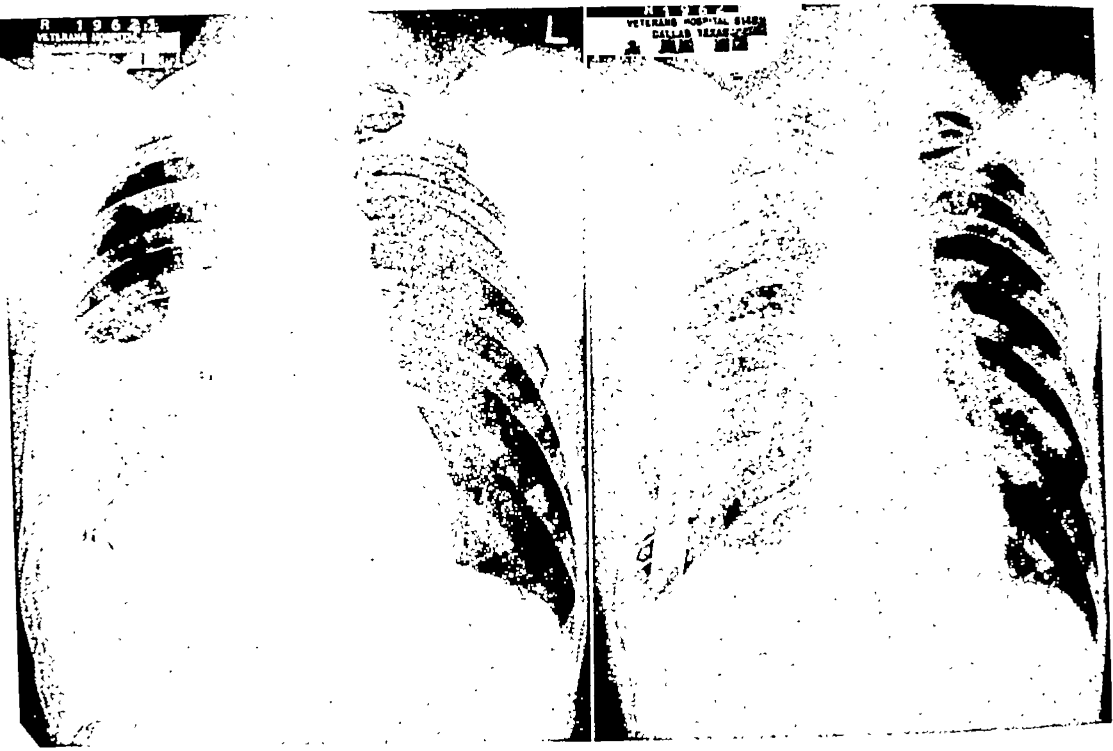
Thirty-five lobectomies were done for patients having active abscesses, fourteen of whom had had previous surgery consisting of drainage in thirteen instances and a previous lobectomy in one. A postoperative empyema developed in nine patients, or an incidence of 25.7 per cent in this group. Twenty-nine of these patients were considered to have obtained a satisfactory result. Five patients were considered to have an unsatisfactory result. There was one death, due to severe hemorrhage from the chest wall to which the abscess was densely adherent. Total pneumonectomies for active putrid abscesses were done in fourteen patients, three of whom had had previous surgery consisting of drainage. There were three postoperative empyemas, or an incidence of 21.4 per cent. Twelve of the fourteen patients were judged to have a satisfactory result in so far as is possible following a complete pneumonectomy. One patient obtained an unsatisfactory result following the removal of a lung for multiple abscesses by the mass ligation technique. He developed an empyema cavity with a persistent fistula which has persisted in spite of a complete thoracoplasty. Reamputation of the bronchial stump will be necessary to effect a satisfactory result. One patient died immediately postoperatively due to cardiac arrest.

Seventeen, or 32.7 per cent, of fifty-two patients undergoing pulmonary resection for active abscesses had had previous surgery consisting mainly of drainage. Fifteen patients, or 28.8 per cent, developed a postoperative empyema. There were two deaths, a mortality of 3.8 per cent. The individual ligation technique of pulmonary resection was used in all instances except for one patient in whom a mass ligation seemed necessary because of the poor condition of the patient.

Residuals of an abscess were resected in eight patients. Two segmental resections and six lobectomies were done. All eight patients obtained a satisfactory result. Two patients had had previous drainage. There were no deaths in this group.

TABLE III. RESECTIONS FOR RESIDUALS OF PUTRID LUNG ABSCESS

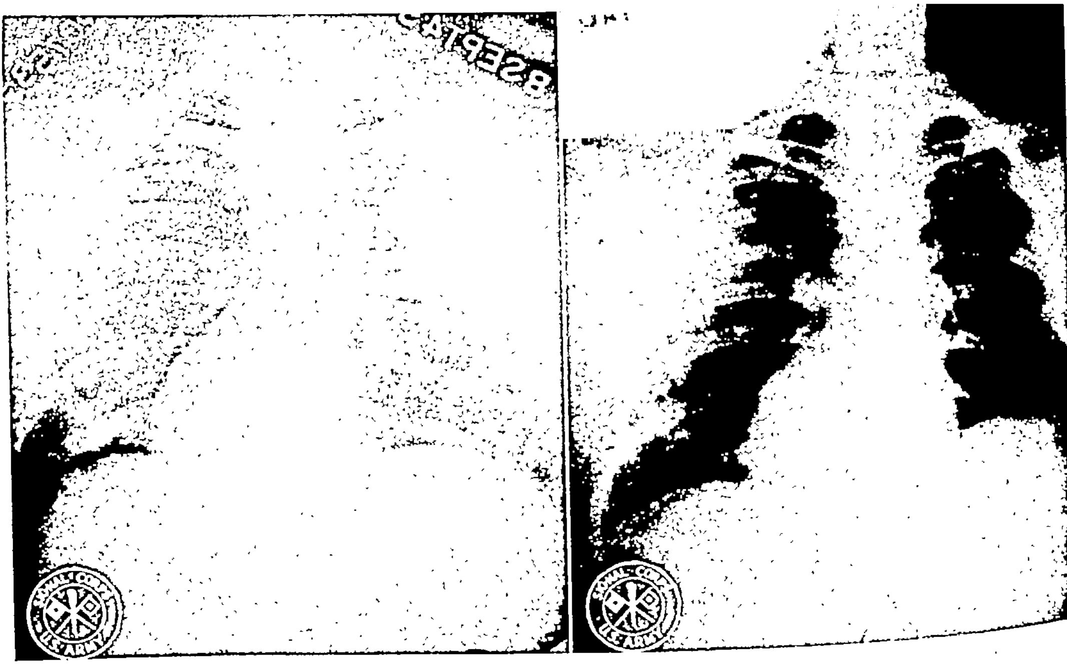
TYPE OF RESECTION	NUMBER	PREVIOUS SURGERY	POST-OPERATIVE EMPYEMA	RESULTS		MORTALITY
				SATISFACTORY	UNSATISFACTORY	
Segmental resection	2	0	0	2	0	0
Lobectomy	6	2	0	6	0	0
Pneumonectomy	0	0	0	0	0	0
Total	8	2	0	8	0	0



A.

B.

Fig. 1.—*A*, Roentgenogram of a patient with a large gangrenous abscess involving the right upper and lower lobes of the lung. *B*, Roentgenogram of the same patient two months after an expedient drainage. A right upper lobectomy and a segmental resection of the dorsal segment of the right lower lobe was done later for removal of the residual cavity.



A.

B.

Fig. 2.—*A*, Roentgenogram illustrating a putrid abscess of the right upper lobe of the lung of nine months' duration. *B*, Roentgenogram of the same patient four months after a primary right upper lobectomy. (Photograph by U. S. Army Signal Corps.)

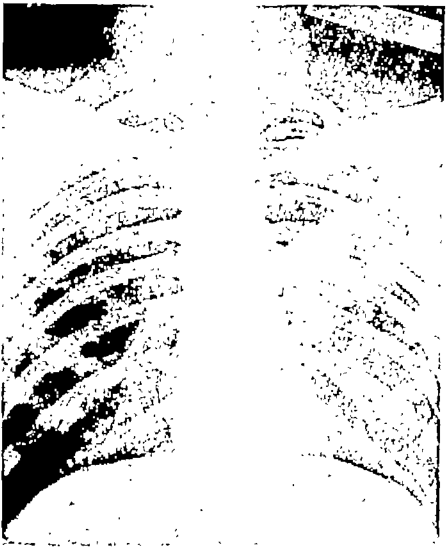


Fig. 3.—Roentgenogram of a patient having a putrid abscess in the left upper lobe of fourteen months' duration; a left upper lobectomy was done.

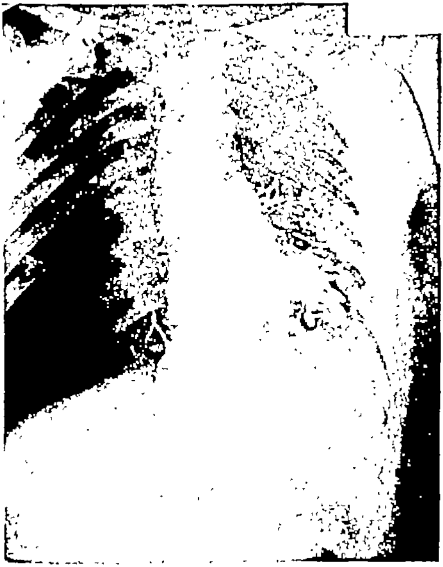


Fig. 4.—Bronchogram of a patient having multiple abscesses in the left lung of four years' duration with marked bronchiectasis; a total pneumonectomy was done.

DISCUSSION

As compared with the previous report made in 1941 by one of us, the mortality of the surgical management of putrid lung abscess has been reduced from 15.2 per cent to 3.5 per cent, and the percentage of satisfactory results or the cure rate has been raised from 57.6 per cent in 1941 to 82.7 per cent in the present series. It is believed that the increased application of pulmonary resection has been responsible for this improvement. Drainage and pulmonary resection in the surgical treatment of pulmonary abscesses are complimentary procedures and are not antagonistic. From a consideration of the pathologic features of abscess of the lung it becomes apparent that drainage alone cannot result in a high percentage of satisfactory results. We are of the opinion that drainage of an abscess should be used only in those patients in whom it is believed drainage will effect a cure or in the group in which drainage is done as a matter of expediency. In all other instances we believe that a primary pulmonary resection should be done. Following the resection for an abscess in this series, 71.2 per cent obtained a primary uncomplicated cure, and 82.7 per cent obtained an eventual satisfactory result. Cough and sputum immediately disappeared and the patient was cured of the disease by complete re-

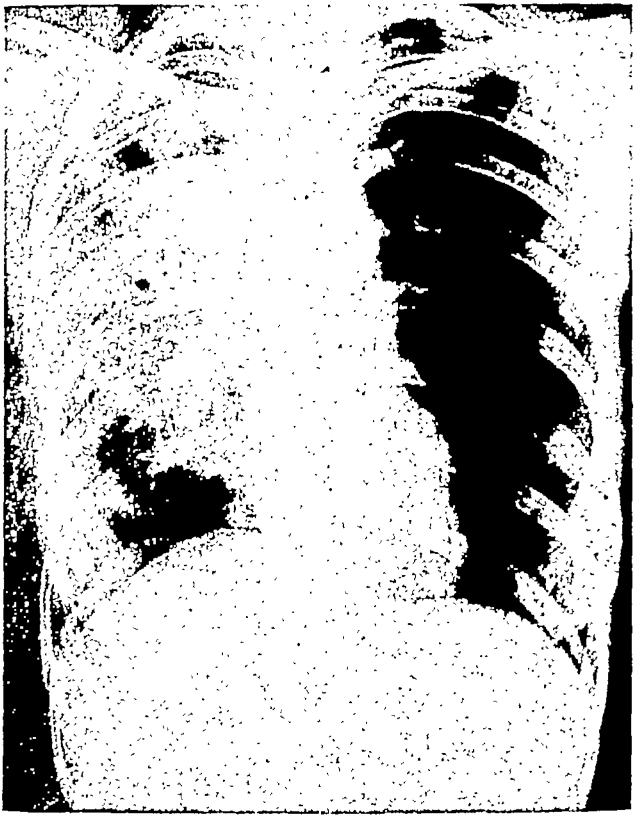


Fig. 5.—Roentgenogram of a patient with multiple abscesses of the right lung of fourteen months' duration; a total pneumonectomy was done.

moval of the abscess as one procedure. The convalescence following drainage is more prolonged but is justified in the interest of the conservation of pulmonary tissue in suitable instances.

It is considered possible that common use of chemotherapeutic and antibiotic agents may be a factor in the lowering of the over-all mortality as compared with the report of 1941. This has been a factor in reducing the mortality of the operative procedure through control of the pneumonitis and cellulitis associated with an abscess. However, these agents cannot be considered as a factor in preventing the development of the pathologic features of chronic abscesses of the lung. During the three-year period of the present report, we have seen fewer patients having acute abscesses than previously. It is our distinct impression that the common use of sulfonamide drugs and the antibiotic agents has in many instances induced a period of quiescence in an acute abscess, thereby lulling the attending physician into the belief that he has cured the abscess only to have an exacerbation occur at a later date. More patients are therefore seen during the chronic stage of the disease, thereby necessitating more pulmonary resections and fewer drainages. Chemotherapeutic and antibiotic agents are of great value as adjuncts to pulmonary resection for abscess, both as preoperative preparation and postoperative prophylaxis. Another and probably equally important factor in the reduction of the over-all mortality has been the development of a more meticulous technique of pulmonary resection as we know it today. Postoperative empyemas occurred in only 28.8 per cent of the pulmonary resections done for abscess of the lung in this series. Most of

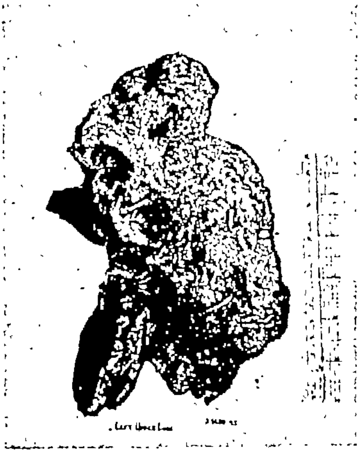


Fig. 6.—Gross pathologic specimen of putrid abscess in the left upper lobe of fifteen months' duration. Note the multilocular cavity, epithelization of the cavity walls, diffuse fibrosis, and dilated bronchi.

these empyemas occurred in patients in whom a previous drainage of the abscess had been done.

It is our observation that segmental resection for abscess of the lung yields a higher incidence of postoperative empyema than does lobectomy or pneumonectomy. Segmental resection may occasionally be indicated for an abscess in the interest of preservation of pulmonary tissue, however, because of the surrounding zone of pneumonitis usually associated with an abscess, transection of lung tissue is dangerous in that infection may be left in the remaining segments.

SUMMARY

A series of eighty-six unselected patients having putrid abscess of the lung treated surgically from 1944 to 1947 has been presented. Eighty per cent of these patients obtained a satisfactory result and the over-all mortality was 3.5 per cent. A comparison was made with a previous series of surgically treated lung abscesses reported by one of us in 1941 in which 57.6 per cent obtained a satisfactory result and 15.2 per cent died. It is believed that the increased application of pulmonary resection is largely responsible for this improvement in morbidity and mortality. The use of chemotherapeutic and antibiotic agents has undoubtedly favored the good results of pulmonary resection.

PULMONARY RESECTION FOR CHRONIC LUNG ABSCESSES

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FRANK S. ASHBURN, M.D., ROCHESTER, MINN.

THE management of chronic lung abscess has always presented one of the more trying problems encountered by the surgeon. This has been especially true of multiple abscesses since these have not responded satisfactorily to drainage operations. Even the solitary chronic abscess has not responded to treatment by drainage in an entirely satisfactory fashion. The morbidity is usually of long duration, the mortality has been of appreciable moment, and the end results have fallen short of the desired goal in many instances.

1. Resection of the diseased lobe or lobes has achieved acceptance as the treatment of choice when surgical intervention becomes necessary in multiple, diffuse or multilocular chronic pulmonary abscesses. Nineteen such cases are included in this presentation in order to demonstrate that the mortality rate can now be expected to be reasonable, the morbidity can be anticipated to be held at a low level, and the end results should be very satisfactory.

2. Eleven cases of solitary chronic lung abscess are presented; each patient was treated successfully by lobectomy rather than by drainage of the abscess. Perhaps resection has not been accepted as yet as the treatment of choice for chronic lung abscesses which are characterized by a solitary cavity, and it is in anticipation of free expressions of opinion on the matter that these cases are described.

A good deal of dissatisfaction with the results of drainage of chronic abscesses led the authors to adopt the policy of elective resection. These disappointing results included very prolonged morbidity, often extending into several months; an appreciable mortality rate; the tendency for these lesions to recur after drainage; and, above all, the consistent residual suppurative changes persisting at the site of the abscess after drainage. Small residual cavities and bronchiectasis of varying degree and extent (Fig. 1) were demonstrated by bronchography in each of six patients studied because of persistent cough and expectoration.

The cases to be presented are arranged in three groups as follows:

Group I includes eleven patients who presented multiple lung abscesses which extended beyond the confines of a single lobe of one lung. The ages of these patients ranged from 21 to 64 years and the duration of the disease from 5 to 42 months with an average duration of 18.0 months (Table I). All were subjected to total pneumonectomy after failure of conservative therapy.

A single patient developed a bronchial fistula after discharge from the hospital. He was readmitted, and the presence of the fistula was established but infection of the pleural space did not occur. The fistula was closed by means

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Read at the Twenty-Seventh Annual Meeting of the American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

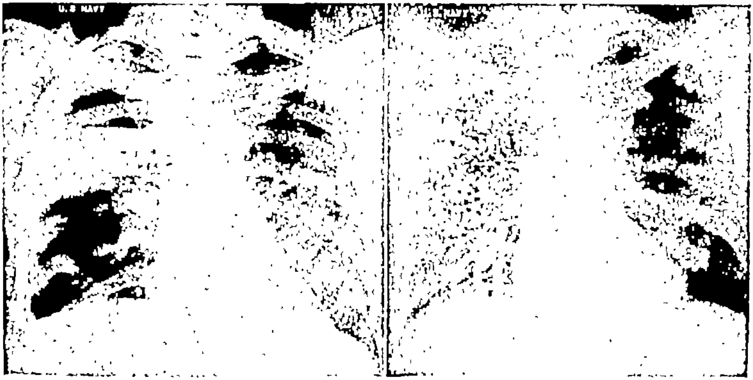
TABLE I. GROUP I, PNEUMONECTOMY FOR MULTIPLE ABSCESSES INVOLVING MORE THAN A A SINGLE LOBE

CASE	SEX	AGE (YR.)	DURATION (MONTHS)	OPERATION	RESULT
1. (B. F.)	M	26	42	R. pneumonectomy	Well
2. (L. H.)	M	21	15	R. pneumonectomy	Death ninth postoperative day
3. (J. J.)	M	64	9	L. pneumonectomy	Well
4. (J. K.)	M	27	18	R. pneumonectomy	Well (Bronchial fistula after operation)
5. (R. N.)	M	56	9	L. pneumonectomy	Well
6. (R. D.)	F	59	11	L. pneumonectomy	Well
7. (A. H.)	M	37	38	R. pneumonectomy	Well
8. (V. B.)	M	56	13	L. pneumonectomy	Well
9. (L. G.)	M	46	40	L. pneumonectomy	Well
10. (C. D.)	M	57	8	R. pneumonectomy	Well
11. (L. R.)	M	54	7	L. pneumonectomy	Well
12. (R. S.)	M	59	5	L. pneumonectomy	Well

Summary of Table: Twelve cases. Age range from 21 to 64 years. Duration range from 5 to 42 months. Five cases on right side, seven on left. One death on ninth postoperative day of extensive pneumonitis of remaining lung, result of gross contamination at operation. One postoperative bronchial fistula but empyema did not occur. Mortality rate this group, 8.3 per cent.

of a pedicled muscle flap which was applied to the fistula opening on the surface of the mediastinum. Five weeks later the fistula reopened and is still open although once more empyema has failed to take place. This patient suffers very little from the presence of the fistula and is not hospitalized. Uultimately, a thoracoplasty will be required if spontaneous healing does not take place. The circumstances in this case are worth recounting briefly. The symptoms of pulmonary suppuration had been of eighteen months' duration. He had been hospitalized four months before pneumonectomy for an acute putrid empyema on the right side which was drained. The underlying multiple lung abscesses were revealed as the empyema healed. Bronchoscopy was performed on several occasions, and a stenosis of the right main bronchus was seen. All efforts to improve the condition of the patient by means of conservative measures failed, and he continued on a progressive, febrile, toxic course. Resection of the lung appeared to offer the only hope of cure, in fact of saving his life. It was a very difficult procedure because of the putrid empyema which had only recently healed. Identification of the hilar structures entailed prolonged dissection and, despite this, the right upper lobe bronchus was divided, and the main bronchus was again divided just below the upper lobe branch. This necessitated repair of two bronchial stumps, neither of which could be buried satisfactorily. These conditions may well explain the occurrence of the fistula. It is interesting to note that examination of the specimen disclosed a cork disk the size of the gasket on a pop-bottle cap lodged in the right main bronchus. The stenosis had occurred about this foreign body. The patient denies any knowledge of how or when the incident took place.

There was one death in this group. This patient was a 21-year-old man who had suffered from multiple abscesses of the right upper and lower lobes for fifteen months (Fig. 2). During this period surgical intervention had been attempted elsewhere on two occasions. An effort to perform drainage of the lesions had been made without success. Later a lobectomy was undertaken but was abandoned after some effort in that direction. He was seriously ill, and all conservative measures failed to provide improvement. Pneumonectomy was decided upon and was carried out. The anesthetist was unfamiliar with the management of these extremely difficult cases, and at one point the tracheobronchial tree filled with contents from the abscesses and asphyxia ensued. One



A. B

Fig. 1.—A, Chronic solitary pulmonary abscess of right upper lobe. B, Lipiodol installation reveals residual cavitation and bronchiectasis at site of abscess. Moderate symptoms persist.

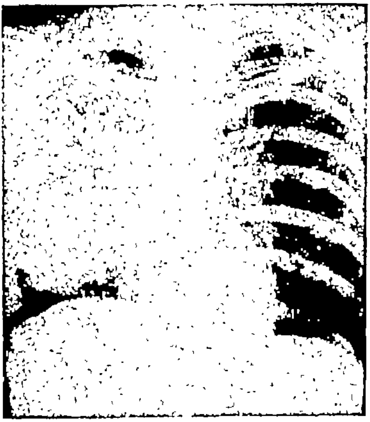


Fig. 2.—(Case 2) Multiple chronic pulmonary abscesses of right upper and lower lobes. Two previous operations elsewhere.

of us dropped out of the operating team and bronchoscoped the patient. The trachea and bronchi were found to be filled with pus and thick, puttylike particles which were aspirated with difficulty. The contents of the abscesses continued to be disgorged into the airway until the right main bronchus was clamped, hence it was necessary to keep the bronchoscope in place throughout the period required to achieve this step in the resection. A diffuse pneumonitis occurred in the remaining lung within thirty-six hours after operation and resulted in death on the ninth day.

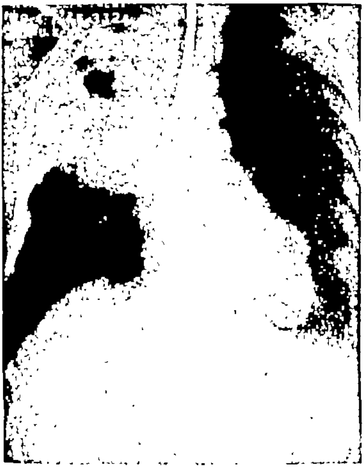
The ten patients which remain passed through uncomplicated convalescence periods and have made full recoveries. While we believe in early ambulation, we have set no definite interval for allowing patients out of bed after pulmonary resection. As a matter of principle, a patient is made ambulatory as soon as he expresses an interest in getting out of bed, if there are no contraindications. This is usually between the third and fifth day after operation. These patients were discharged from the hospital at periods varying between ten and sixteen days after surgery.

Group II includes seven cases of multiple abscesses confined to one pulmonary lobe. The age range varied between 25 and 46 years. The duration of symptoms ranged from nine to thirty-nine months with an average of 20.5 months for the group. All were subjected to lobectomy (Table II). There were no postoperative bronchial fistulas or infections of the pleural space. There was one death which occurred on the operating table due to asphyxia caused by hemorrhage into the tracheobronchial tree from the diseased lobe. This patient had been under treatment elsewhere for thirty-nine months because of multiple abscesses of the right upper lobe (Fig. 3). Two drainage operations had been performed without favorable results. Daily hemoptysis had been present for five months, and these were of such magnitude that repeated blood transfusions were required. The situation was indeed desperate; nevertheless, an attempt at resection was elected. The fatal hemorrhage occurred as the chest was being opened, and it caused death by asphyxia. It is possible that earlier recognition of the cause with immediate bronchoscopy would have prevented death at that time. Postmortem examination revealed that lobectomy would have been virtually im-

TABLE II. GROUP II, LOBECTOMY FOR MULTIPLE ABSCESSES CONFINED TO A SINGLE LOBE

CASE	SEX	AGE	DURATION (MONTHS)	OPERATION	RESULT
13. (G. N.)	M	26	17	Middle lobe	Well
14. (R. H.)	M	31	11	Middle lobe	Well
15. (J. M.)	M	44	9	Middle lobe	Well
16. (S. A.)	M	25	19	Left upper lobe	Well
17. (J. S.)	M	36	39	Thoracotomy	Death on table of asphyxiation from hemorrhage
18. (A. W.)	M	24	29	Left lower lobe	Well
19. (A. M.)	M	46	20	Right upper lobe	Well

Summary of Table: Seven cases. Age range 25 to 46 years. Duration range from nine to thirty-nine months. No postoperative bronchial fistulae or empyemas. One death on the operating table due to hemorrhage from the abscesses and asphyxia. Mortality rate for this group is 14.3 per cent.



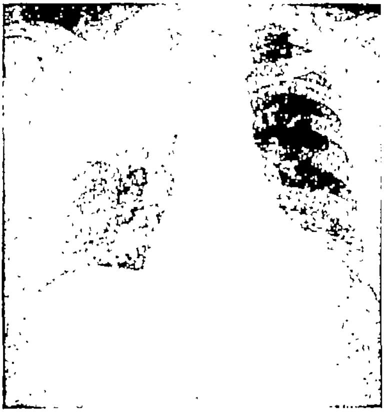


Fig. 3.—(Case 17) Multiple chronic pulmonary abscesses of right upper lobe. Catheter in trachea in effort to fill diseased lobe with iodized oil. Two previous operations elsewhere.

Fig. 4.—(Case 19) Multiple chronic pulmonary abscesses of right upper lobe. Drainage operations performed twice elsewhere.

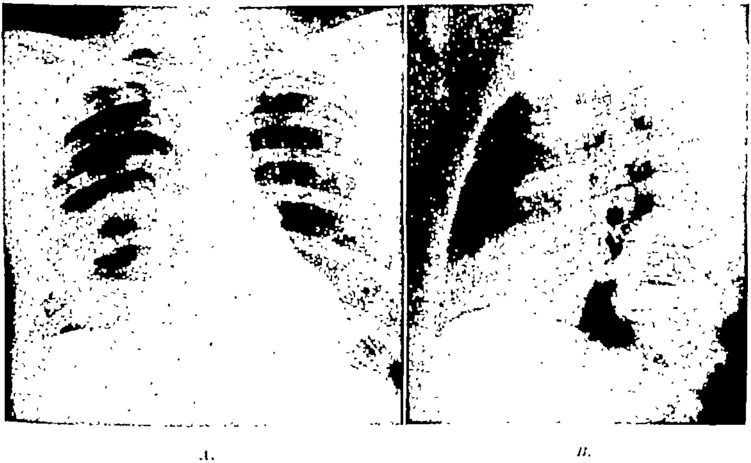


Fig. 5.—*A* (Case 23), Solitary pulmonary abscess of right lower lobe, five months' duration. *B*, Lateral view, same patient.

possible. The six patients who remain in this group passed through the postoperative convalescence period without complications, were out of bed no later than the seventh day, and were ready to leave the hospital on or before the seventeenth day after operation.

Three of these patients had received at least one previous attempt at surgical drainage (Fig. 4). Two of them had been drained upon two previous occasions. Technical problems are greater under such circumstances, particularly because the lobe becomes extremely adherent to the chest wall at and about the site of drainage and because perforation of the diseased lobe at the site of previous drainage is quite likely to occur with resulting contamination of the pleural space.

Group III includes eleven patients with solitary abscess of the lung, each of whom was treated by lobectomy (Table III). The ages of these patients varied from 17 to 56 years and the duration of disease from four to thirty-seven months with an average duration of 11.5 months. Two of these patients developed small bronchial fistulas with empyemas of rather limited size after operation. There were no deaths in this group, and all are well at this time. A typical case from this group is displayed in Fig. 5. A large, thick-walled abscess was present which was easily accessible for surgical drainage; nevertheless, lobectomy was elected as the treatment of choice and this particular case was one of the most difficult to resect in this entire group. The postoperative convalescence was entirely satisfactory, and the patient left the hospital on the tenth day after operation.

TABLE III. GROUP III, LOBECTOMY FOR SOLITARY CHRONIC PULMONARY ABSCESS

CASE	SEX	AGE	DURATION (MONTHS)	OPERATION	RESULT
20. (R. W.)	M	24	5	Right lower lobe	Well
21. (J. C.)	M	20	9	Left lower lobe	Well
22. (V. H.)	F	18	26	Left lower lobe	Well
23. (J. M.)	M	27	5	Right lower lobe	Well
24. (D. M.)	F	34	37	Right lower lobe	Well
25. (G. S.)	F	17	4	Right upper lobe	Well (Bronchial fistula with empyema)
26. (F. G.)	M	36	7	Right upper lobe	Well
27. (B. J.)	M	19	4	Right lower lobe	Well
28. (J. B.)	M	46	8	Right lower lobe	Well
29. (S. R.)	M	56	18	Right upper lobe	Well
30. (Z. M.)	F	43	5	Right lower lobe	Well (Bronchial fistula with empyema)

Summary of Table: Eleven cases. Age range 17 to 56 years. Duration range four months to thirty-seven months. Two developed postoperative bronchial fistula with empyema. No deaths occurred. Two of these cases had been drained elsewhere with recurrence of the abscess or failure to heal.

The choice of resection rather than surgical drainage for patients presenting a solitary pulmonary abscess has been deemed justifiable due to the unfavorable results achieved by the latter means. The series is small, and further experience may prove that the risk is greater than that entailed in drainage of an abscess. If that proves to be the case, we shall be compelled to revert to drainage operations. However, if the mortality rate is found to be no higher, we feel that it will become the procedure of choice since the morbidity is greatly reduced and the end results are much more consistently of a satisfactory character.

It should be made clear that we are not choosing resection for the treatment of refractory acute pulmonary abscesses but are limiting it to use in cases of long standing, chronic pulmonary abscesses.

The role of the anesthetist is extremely important in all forms of thoracic surgery, and it is vital in cases of chronic pulmonary suppuration. Perhaps the most exacting duty which falls upon him is prompt recognition of the presence of secretions in the airway and the immediate removal of same. This often requires the frequent use of the bronchoscope during operation since catheter aspiration of the airway is inadequate in many instances.

We are convinced that penicillin has been of great value in reducing infections of the pleural space and virtually eliminating wound infections after surgery for cases of this type. Nevertheless, the most important factor in reducing postoperative suppuration has, in our opinion, been the use of the individual ligation technique for pulmonary resection.

SUMMARY

1. Thirty cases of chronic pulmonary abscesses have been treated by pulmonary resection. Nineteen were cases of multiple diseases and eleven were of solitary abscesses.

2. Eight of these patients had received one or more previous operations for the treatment of these lesions.

3. The average age for the entire group is 33 years, minimum age 17 years, maximum age 64 years.

4. The average duration of disease in the entire series is 16.2 months, minimum duration four months, maximum forty-two months.

5. There were two deaths (6.6 per cent) in the entire series. These have been described in detail.

6. Greater experience with resection for solitary pulmonary abscess will be necessary before the safety of the procedure can be established. The end results were excellent in the eleven such cases of this series.

7. The postoperative morbidity is sharply reduced in contrast to that experienced after drainage of solitary pulmonary abscesses.

8. The end results following resection for chronic pulmonary abscess promise to be favorable with higher constancy than after drainage.

DISCUSSION

DR. JAMES D. MOODY, Durham, N. C.—I would like to ask Dr. Paulson what incidence of contralateral and ipsilateral spread he has had in his cases of resection. I note that Dr. Kent has had some difficulty with it.

During the past several months we have been working on an instrument designed to obstruct the bronchus and prevent the spread of purulent secretions during pulmonary resections.

(Slide) On this slide is depicted the instrument which we have finally developed; you will note that it consists of a small rubber balloon mounted on the end of a double-lumen, 12 French, rubber catheter.

I am sure you are all familiar with the disadvantages of some of the instruments which have been developed in the past, namely, that they have tended to slip out of place at inopportune times. We have attempted to get around that by constructing this metal apparatus which fits around the balloon in this manner. As you note, it has several small one millimeter points at the ends. This holding apparatus, as we call it, is made in three sizes to fit the varying diameters of the bronchi where the balloon is placed.

(Slide) On this next slide is depicted the manner in which the points of the holding apparatus are embedded in the bronchial mucosa. On deflation of the balloon, the points resume their original position, and the entire apparatus may be withdrawn from the bronchus without harm to the bronchial mucosa.

The proximal end of the double lumen catheter is connected to a sleeve valve which, when closed, maintains inflation of the balloon. This enables us to place the balloon in the bronchus and then remove the bronchoscope without fear of dislodging the balloon.

(Slide) This is a diagram of the function of the balloon in a theoretical patient with lung abscess. You will note the large lung abscess with a fluid level and the balloon obstructing the left lower bronchus, thus sealing off any drainage from the abscess.

For a pneumonectomy on the left side, the balloon is placed between the carina and the left upper lobe orifice. For a pneumonectomy on the right, it should be placed at this spot, and at the corresponding levels for resection of the right middle and/or lower lobes.

During the past ten months we have employed this instrument in a series of twenty-three cases in order to work out a technique for the instrument. Of these twenty-three cases, approximately one-half of them were done for bronchiectasis, five for tuberculosis, and the remainder for carcinoma and lung abscess. Bronchial occlusion has been perfect in all cases. This has been evidenced either by atelectasis of the affected lobe or by lack of inflation on positive pressure anesthesia.

I failed to mention that the instrument has a twofold purpose. It is designed to obstruct the bronchus to the affected lobe, and also to produce atelectasis distal to the balloon in the bronchus. The atelectasis, of course, gives the surgeon much more room within which to work; he may, therefore, maintain inflation of the upper lobe on that side if he so desires, providing he is doing a lobectomy.

There has been no interference with anesthesia in any of our cases. In fact, anesthesia has been considerably aided through obviating tracheobronchial suction. There have been no harmful effects in any of the patients. Four of the patients had thoracotomies without removal of pulmonary tissue.

The mechanics of placement and operation of the instrument have proved quite simple over a period of several months. The balloon has retained its primary function of remaining in place securely in all except one case. In this particular instance, the bronchus was a mass of tuberculous granulation tissue, and it was thought preoperatively that the balloon would not remain in place. However, it did so much longer than was expected.

Inasmuch as this series of patients was used in working out a technique for the use of the instrument, we have not expected, of course, 100 per cent success. We have had three contralateral spreads, all occurring in the first few cases in the series, and fortunately, all quite minimal. There are certain factors explained in the paper on this subject which we believe may account for the spreads having occurred at the time when the balloon was not in the bronchus.

The results in these cases are considered quite satisfactory, and we hope to employ the balloon, along with improved methods of bronchoscopy and pre- and postoperative care, in a large series of patients during the coming year, in order to determine whether or not the instrument may reduce the incidence of contralateral spread.

DR. DUANE CARR, Memphis, Tenn.—I am sure that most of the men would agree that resection is the treatment of choice for multiple lung abscesses scattered throughout a lobe or entire lung.

Dr. Kent has pointed out one of the difficulties which may arise in the execution of such a procedure, that of the excessive amount of secretion which will produce flooding of the bronchi of the opposite lung. Many here have become convinced of the advantages of the face-down position of the patient on the operating table in such a situation.

However, tables designed for this purpose, such as the one demonstrated at this meeting, are not available to all of us.

Dr. Skinner and I were faced with this problem in a young girl who had extensive abscesses scattered throughout one lung, and although we had bronchoscoped the patient previous to the induction of anesthesia and during the operation, we were forced to discontinue the procedure before its completion.

We were forced to improvise an attachment to permit a face-down position and found an ironing board with six inch blocks to support it adequate for the purpose. A section of the board was cut off with a saw to permit the incision to be extended around to the anterior axillary line. In this fashion the patient was elevated from the table and adequate room was allowed for an excellent exposure.

Ten days later Dr. Skinner and I were able to complete the operation and the ease with which this patient went through the anesthetic and the operation was amazing. No difficulty was encountered in keeping the trachea and bronchi clean and the patient made a satisfactory recovery.

So for those of you to whom a thousand dollar table especially adapted to the face-down position is not available, an ironing board, a couple of six inch blocks, and a saw will permit you to operate upon these patients without the complications of flooding the contralateral lung with pus.

DR. RALPH A. DORNER, Iowa City, Iowa.—At the University of Iowa we have a series of twelve pulmonary resections for abscess of the lung since 1941. Two of these were pneumonectomies and others lobectomies.

There was one mortality. This death occurred in the case of a white woman 28 years old who had been seen at the University Hospital off and on since 1938 with bilateral lung abscesses. Her chief symptoms had been recurring attacks of pleurisy and hemoptyses. In 1943 she spent eleven months in the Iowa State Tuberculosis Sanatorium, where many studies for tubercle bacilli, including cultures and guinea pig inoculations, were negative. During this stay, a right phrenemphraxis was performed and there was a resultant temporary cessation of hemoptyses. However, in April 1945, they again recurred and became frequent and severe.

Hoping to eliminate the cause of her bleeding, bilateral lobectomies were advised. On Aug. 9, 1946, I did a right thoracotomy. Both the middle and lower lobes were found to be involved in a marked inflammatory process and were, therefore, extirpated. Immediate postoperative bronchoscopy revealed blood coming from the *left* main-stem bronchus. Studies of the tissue removed showed a number of abscesses with a central necrotic area containing foul, thick, greenish pus surrounded by a 3 to 5 mm. zone of dense connective tissue. There was some associated bronchiectasis, atelectasis, and pneumonia. Cultures of pus from the cavities revealed *Monilia albicans*, as had been found once in her sputum preoperatively. Subsequent sputum studies revealed large amounts of the same organism in numerous specimens.

The patient had a rather stormy postoperative course. X-rays showed clouding of both lung fields—apparently due to a spread of infection from the hemorrhage. This appeared to increase, although the patient's condition seemed to improve. The patient began having paroxysms of marked dyspnea and insisted that she was going to die. She did die during one of her attacks of paroxysmal dyspnea on the twenty-first postoperative day. Unfortunately, we were unable to obtain permission for an autopsy and thus were unable to study the case further as to whether her abscesses and death had been due to *Monilia albicans*.

A second case of particular interest to us was a white man 45 years old. He had had the onset of a lung abscess following the "flu" in June, 1946. He was admitted to the Iowa State Tuberculosis Sanatorium on Nov. 18, 1946, because of the suspicion of tuberculosis due to the cavity in the right upper lobe. He was raising from two to five cupfuls of foul-smelling sputum per day. Many studies for tubercle bacilli were negative. Likewise, frequent bronchoscopic examinations failed to reveal the presence of a tumor.

Feeling that this chronic lung abscess obviously would not respond to simple drainage, and fearing that we might be dealing with a carcinoma, we felt that this patient deserved exploration. I explored him in February of this year, and found a woody right upper lobe. The process, confined entirely to the upper lobe, appeared inflammatory and there was no evidence of node involvement. Consequently, I carried out a right upper lobectomy.

(Slide) The examination of the specimen postoperatively revealed a very marked inflammatory reaction within the entire right upper lobe, with the cavity shown in this slide partially opened. Grossly, the pathologist noted numerous "tiny golden dots" which microscopically were interpreted as actinomycetes.

Some of the tissue was taken immediately to the bacteriology laboratory, and their studies revealed the presence of actinomycosis.

This patient's postoperative course was somewhat disturbing for a few days. He raised a fairly large amount of sputum, and we had the impression that he had an atelectasis of his middle lobe, probably due to distortion of the middle lobe bronchus. I had placed a water-sealed catheter into the thoracic space at operation. The water seal was converted to active suction, and this apparently relieved the distortion of the middle lobe bronchus with very rapid disappearance of the atelectasis and obliteration of the apical space.

The patient's postoperative course from then on was satisfactory. He was given penicillin, 50,000 units every four hours, until his discharge on the twenty-second postoperative day. He has been seen several times since discharge and appears quite well.

DR. ROBERT R. SHAW, Dallas, Texas.—Surgical drainage of an acute pulmonary abscess yields a highly satisfactory result in almost every case, with maixmum preservation of pulmonary function.

There seem to be two factors that are leading to the increased application of resection in the treatment of this disease. First, of course, is the factor of the increased safety of pulmonary resection, due to refinements in technique of the handling of the hilum, of anesthesia, and in adequate blood replacement. Second, there is the factor of the increased use of antibiotics in the early treatment of this disease. We all know that antibiotics, chiefly penicillin and the sulfa group of drugs—I, myself, have had no experience with streptomycin—will induce in many of these patients a period of quiescence which lulls the physician into feeling that the patient is probably all right. Only later it will be found that thas patient continues to have symptoms and flare-ups of the disease, and at this time it will be found that the complicated features of this disease have already become established. Once these features have become established, simple drainage of the abscess will usually not alone effect a cure. That, of course, brings us into the increased use of pulmonary resection.

I want to congratulate Dr. Kent and Dr. Ashburn on their very low percentage of empyema. We have not been able to achieve as low a percentage as they have achieved. I can look back upon several cases in which the occurrence of the empyema was definitely due to a technical fault of my own. In two patients having pneumonectomies, I left an unnecessarily long bronchial stump, and I am sure that contributed to a bronchial fistula with empyema. They subsequently received good results, following a complete thoracoplasty for the empyema. In one other patient—much the same as Dr. Kent described in telling of the fatality, a patient who had had a previous drainage and also a previous attempted resection—while operating under unfavorable circumstances in a strange hospital, I had to use mass ligation technique to get out of the chest expeditiously and save the patient's life. This resulted in a very long stump, in that the bronchi were actually cut at the branches and not at the main bronchus. This patient is alive, but does have symptoms due to this long bronchial stump, and I am planning to amputate it at a later date. I hope that eventually he will obtain a good result.

In other cases it may be thought wise even to invite the complication of an empyema in order to preserve pulmonary function. I do not think that we should be concerned only with the preservation of pulmonary function in people of middle age, or perhaps the elderly group. We hope that the person of 20 and 30 years will arrive at the age of 50 or 60, and then pulmonary function will become very important to him. So that in every patient I think we should strive to preserve as much normal pulmonary tissue as possible. Because of that, I have at times elected to break into infected areas along fissure lines, where the only extension into the neighboring lobe is along a fissure line, and in that way I have obtained a postoperative empyema. I do not feel that the increased morbidity that this patient incurs is important when considering, also, the better result that he will get from the residual pulmonary tissue that was left behind.

DR. ANTHONY R. CURRERI, Madison, Wis.—I believe the essayists should be commended for demonstrating the low rate of mortality associated with pulmonary resection in the treatment of chronic lung abscess.

We welcome this discussion, because for a long time we entertained a notion that our approach to this problem was a very radical one. We have employed pulmonary resection in chronic lung abscesses since 1939. Originally, it was used in instances of multilocular abscesses because of high mortality and morbidity.

With the introduction of the individual ligation of the hilar structures, there was a tremendous improvement in the mortality and morbidity rate. With the refinements in anesthesia, as mentioned by Dr. Shaw, and improvements in pre- and postoperative care, and our own greater experience in pulmonary resection, the operation is now relatively safe.

We believe it is the operation of choice for chronic lung abscess, because, first, it eliminates the disease immediately; second, there is no possibility of the development of sequelae such as bronchiectasis; third, the disturbing complications of hemorrhage, embolic brain abscesses, and the persistent and annoying bronchopleural fistula are done away with; and fourth, we do away with the prolonged convalescence.

Recently we received the pulmonary resections of the past two years, and noted thirteen cases of chronic lung abscess. We did not include any case of extensive bronchiectasis with marked alveolar attacks, nor congenital cystic lungs with secondary infection.

Of this group of thirteen, there were seven on the right side and six on the left side. The duration of symptoms was from three months to three years. The average stay in the hospital was seventeen days, with the shortest period ten days, postoperatively, and the longest twenty-four days.

We believe the immediate results have been very good, although a final statement regarding prognosis cannot be made until a few years have elapsed. There has been no fatality in our series.

I would like to mention that in regard to control of sputum we have employed a Trendelenburg position of 20 degrees.

DR. EDWIN J. GRACE, Brooklyn, N. Y.—In the early summer of 1943 I had the opportunity of reviewing the work on aerosols being done by Dr. Vernon Bryson as a civilian scientist doing research for Chemical Warfare Service at Cold Spring Harbor. I subsequently became associated with him and we endeavored to see what could be done in furthering the use of aerosol therapy as a method of treating pulmonary disease.

We concluded from animal experiments that a more efficient method of using aerosols might be to depend not on antibiotics alone, but to use them with wetting agents (or detergents), thereby possibly increasing the penetration of suppurative material and providing certain more obvious advantages which I will specify in a moment.

If we come back to the fine philosophy so strongly emphasized yesterday by Dr. Graham and live with fundamentals we rarely go wrong. Following this reasoning we observed, and put to use clinically the observations of Dr. Demerec, the Director of the Department of Genetics, Carnegie Institution of Washington. He has shown that there is a possibility of resistant strains developing if inadequate amounts of penicillin are employed. I might also say that this significant observation was noted in an editorial in the J. A. M. A. If we are going to employ antibiotics at all we must use them in large and adequate doses. Failure to do so may account for the comment sometimes heard that aerosol therapy produces clinical improvement that is too often followed by remission. The antibiotic must be brought in direct contact with the organism if you are going to eliminate infection. Florey has constantly emphasized this fundamental.

With our specific problems of pulmonary infection, we must realize that if we give antibiotics parenterally, only a small percentage actually reaches the infecting organism in the lung. The ideal method, we feel, is to use parenteral injection only as a secondary supplement to the infinitely more important fundamental of topical application.

Depending on the disease involved, we feel that more effective treatment for suppurative disease of the lung may be obtained by aerosol therapy, using penicillin or streptomycin, with combinations of the two where indicated by bacteriologic findings. Our present clinical results reveal that the use of a suitable detergent as a vehicle for inhaled antibiotics may be the method of choice. Use of detergents is based on the findings of Dr. Bryson that the activity of penicillin, and, to a lesser extent, streptomycin, may be significantly enhanced by detergents as demonstrated by experiments in vitro and upon animals with pulmonary disease. In addition, the possibility of increased penetration and the specific germicidal effect of certain detergents, such as members of the quarternary ammonium series upon antibiotic resistant organisms, must be considered in preparing active antibacterial preparation designed to minimize the likelihood of resistant strains becoming established as clinical entities. In particular, it is important that doses of penicillin and detergent that will reduce but slightly the number of pathogenic bacteria when used separately may completely eliminate the bacteria when an antibiotic-detergent combination is employed. The effect on staphylococci and pneumococci can be shown to be far more than additive and corresponds to the process ordinarily defined as synergism. The therapeutic result may then be more favorable than might be anticipated from the sum total of the antibacterial substances used. We use penicillin with streptomycin in a detergent which is a moderate bactericide and in addition, by mouth, we very often use some of the sulfa derivatives.

DR. RALPH B. BETTMAN, Chicago, Ill.—We would like to have you state the kind of detergent that you used.

DR. GRACE, Brooklyn, N. Y.—We have used an extremely efficient detergent dealing with cases of chronic osteomyelitis, namely Aerosol O.T. or Aerosol Wash., closing twenty-four out of twenty-nine cases. These chemicals should not be confused with the general term, aerosol . . . meaning a suspension of fine particles in a gas.

In our cases of pulmonary suppuration, we have used Zephiran chloride 1:1,000 aqueous solution as a vehicle for antibiotics. We dissolve 300,000 units of penicillin in 3 c.c. of Zephiran chloride or add 300,000 units of streptomycin to 100,000 units of penicillin in Zephiran depending upon the diagnosis. The patient inhales aerosol every six to eight hours, using a nebulizer operated from an oxygen tank. We make it a point that the patient exhales forcibly and then breathes very, very deeply. Zephiran is a more potent germicide than Aerosol O.T. but a less efficient wetting agent.

The perfect detergent is one which will do three things: (1) act independently as a germicide; (2) reinforce antibiotic activity by synergistic effect, and (3) act as a penetrating agent to insure contact with necrotic substance. We feel that with an efficient detergent we might be able to pentrate he necrotic material of which Dr. Block has spoken.

In a very limited series of cases of pulmonary tuberculosis (eleven), we have three patients with large cavities who were freed of tubercle bacilli and whose cavities were closed after treatment with antibiotics ranging from four weeks to nine weeks, employing a detergent and producing synergistic action in the method described a moment ago. The other eight cases have shown improvement but at this early date it is not possible to make a sound evaluation.

In closing, I want to make an urgent plea. I would very strongly recommend that, as a prophylactic measure in itself, when any suppuration is involved, you use this method as an excellent preoperative preparation, and I think many of the men will be amazed at how frequently some of their lung abscesses may disappear if treated on this basis, using detergents. Certainly, before any major operative procedure for tuberculosis or other suppurative disease of the lung is performed, the conservative and nonmutilating method of antibiotic-detergent aerosol therapy should be used.

DR. J. KARL POPPE, Portland, Ore.—I have been interested in the problem of the comparative mortality of drainage and resection in lung abscesses for some time and have attempted to review a long series of cases at Barnes Hospital in St. Louis to get a more accurate estimate of that comparison.

In reviewing this series I found great difficulty in differentiating lung abscesses and bronchiectasis. That may sound peculiar, but a number of the chronic lung abscesses we resected showed only bronchiectasis on the pathologic sections, the distinction there being whether or not the cavity or cavities were lined by epithelium. That distinction or that state of the abscess bore a very definite relationship to the mortality rate on resection.

The undrained abscesses or poorly or inadequately drained abscesses had a mortality rate that was approximately twice that of the resections for bronchiectasis. That mortality varied considerably from year to year. The series went back to 1920, at which time the mortality rate for both lesions was considerably higher. It decreased progressively during the period up until about 1942, but the comparison was still about 50 per cent higher for the undrained abscesses.

After a cautery pneumonotomy had been performed in a certain number of these cases, even though a lobectomy was still required, the pathology was entirely different. We no longer had a true abscess on pathologic examination. We had epithelium-lined, well-drained cavities, which really constituted bronchiectasis. This situation may have changed now, with the reduction in virulence of the organisms by penicillin. I thought it was very interesting that the mortality varied so much with the condition of the abscesses, depending largely on previous drainage and chronicity.

DR. OTTO C. BRANTIGAN, Baltimore, Md.—I hesitate to prolong the discussion, but I think the essayists should be commended on their very excellent work and its presentation. I am sure there is no question in the minds of the members of this society concerning the efficiency or the desirability of pulmonary resection in the treatment of chronic lung abscess. Surgical drainage of chronic lung abscess in the past resulted in a mortality rate of 35 to 60 per cent. With a mortality rate as low as that reported by the authors, pulmonary resection by comparison is a very conservative method of treatment.

Aside from the lower mortality and the higher percentage of patients cured by pulmonary resection or chronic lung abscess, such a method of treatment is a safeguard against carcinoma of the lung associated with lung abscess. Often it is impossible definitely to eliminate carcinoma of the lung when lung abscess is present. During the past two years I have started the operation for chronic lung abscess only to find in three patients an associated carcinoma when the thorax was opened. In each case the lung was removed.

In my experience there has been no difficulty with spread of infection to the other side, but in the past two years patients have been placed in the face down position during operation. A special operating table has not been available but the neurosurgical cerebellar attachment for the usual operating table has been used and found quite satisfactory.

DR. DONALD L. PAULSON, Dallas, Texas.—In the presentation of our material, I neglected to state that the individual ligation technique was used in all cases except for this one case which Dr. Shaw described in his discussion, in which a mass ligation was considered advisable.

As to the incidence of contralateral or ipsilateral spread, we have had only one case of what might be considered a direct extension from a right upper lobe abscess into the right middle lobe. At the time of resection of the right upper lobe abscess this was recognized, but it was decided to take a chance on this process being reversible, and preserve the middle lobe. It was necessary at a later date to go in and resect the middle lobe. There have been no contralateral spreads.

I agree with Dr. Grace that the value of antibiotics is very great in the preoperative preparation of these patients for surgery, and in the prophylaxis of the development of pneumonitis, cellulitis, and empyema postoperatively.

Certainly in any case in which carcinoma is suspected from the patient's history or the findings, a thoracotomy should be done to determine the precise nature of the lesion.

DR. E. M. KENT, Pittsburgh, Pa.—Contralateral spread is a problem. We had two additional cases which responded to antibiotic therapy. We have not used the face-down position. We have had to use bronchoscopy, as indicated, during operation and at the close of the operation. I think that possibly the face down position is the ultimate answer to most all of these spreads, whether they are tuberculous or nontuberculous cases.

It was mentioned that carcinoma frequently is responsible for chronic or chronic-appearing lung abscesses, and that is quite true. None of those cases have been included in this group presented today, but it is so important a consideration in the diagnosis of that disease that very often resection is necessarily elected because of the uncertainty in patients of the carcinoma age group, and it has been mentioned earlier, I think, by one of the men, that about one-third of the cases they resected on that assumption proved, after the removal of the lung, to be on a carcinomatous basis.

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CLOSED INTRAPLEURAL PNEUMONOLYSIS

An Analysis of 1,000 Consecutive Operations

J. Claude Day, M.D., and (by invitation) Paul T. Chapman, M.D.,
and E. J. O'Brien, M.D.
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THAT pneumonolysis is essential to a properly balanced program of collapse therapy is axiomatic. Its judicious and skilled application in as many pneumothoraces with restraining adhesions as is consistent with safety is desirable. Its complete omission or infrequent use may be as harmful as its too ambitious application. We are not in accord with a current tendency to regard it as a procedure which should be employed universally in every pneumothorax with adhesions, and, conversely, we feel that the failure to utilize it to its fullest capacity when the indication is clear is inexcusable.

It is the purpose of this paper to study the effects of pneumonolysis upon the course of pneumothorax; to examine the factors thought to be responsible for the significant complications; to report the present status of the patients after a follow-up period of from six months to seven years, and to attempt an evaluation of the ultimate fate of the pneumothorax in relation to pneumonolysis.

It has been our feeling that many of the reports dealing with the results of pneumonolysis have been limited too strictly to the immediate postoperative period. The failure to recognize that the eventual fate of the pneumothorax may be and often is inseparably linked with the influence which the pneumonolysis has exerted on its course, has mitigated against an accurate evaluation of either. Such preoccupation with the operation itself and failure to accept the occurrence of many late complications as directly related to the operation are not consistent.

The early recognition of the importance of pleural adhesions in preventing effective pneumothorax led to attempts to devise methods for freeing them. Friedrich, in 1908, first divided adhesions through an incision into the pleural cavity. This method of open pneumonolysis was used much later with considerable success by Anderson and Alexander,[1] O'Brien,[2] and Carter.[3] Although before the perfection of intrapleural pneumonolysis it was thought to have a respectable place in the surgical treatment of tuberculosis, its many obvious disadvantages soon eliminated it almost completely. It is mentioned here only to condemn it. Its recent revival in certain isolated clinics is to be deplored.

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Read at the Twenty-Seventh Annual Meeting of the American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

The operation for the severance of adhesions under endoscopic guidance was devised by Hans Jacobaeus[4] in 1913. The method employed by him, modified by Unverricht,[5] and later improved by the introduction of newer types of telescopes, electrosurgical cutting instruments, and various accesesory equipment, is still the most widely used. Ralph Matson[6] popularized the operation in this country and was the first to discard the galvanocautery for electrosurgery. He devised electrodes which were described by Moore[7] as the most useful to be had for intrathoracic work. Moore[7] has used the electrosurgical method exclusively.

Davidson[8] and Cutler[9] in this country and Chandler[10] in England were the first to devise an instrument combining the telescope and cutting electrode adaptable to use through a single portal of entry. The O'Brien modification of the Davidson-Cutler thoracoscope has gained wide popularity in recent years and was used by us exclusively in this series. Though many advantages are cited by the proponents of both methods, it is likely that the results of experienced operators will not be significantly different.

Because of lack of uniformity in selection of patients for operation and in definition of complications, this procedure lends itself poorly to analysis, and comparison of statistics is difficult.

Matson[6] reported that in 152, or 61 per cent, of 249 patients the operation was technically and clinically successful; an additional nineteen (7.6 per cent) were clinically successful despite incomplete operation; in two who died operation had been technically successful. Forty-one, or 16.5 per cent, developed pure tuberculous empyema.

Jacobaeus had technical success in 80.7 per cent of 150 patients and early clinical success in 66 per cent. He reported eleven, or 7.4 per cent, of empyema deaths among his, Gravens' and Holmboe's 148 pneumonolysis cases.

In 1934 Moore[7] reported 75.5 per cent clinical success in 1,850 collected cases. The incidence of tuberculous empyema in 2,043 collected cases was only 2.2 per cent and that of mixed infection empyema 1.8 per cent.

Drash[13] in 1938, using the Davidson-Cutler thoracoscope, reported the occurrence of only 2.6 per cent tuberculous empyemas and no mixed empyemas in his series of 251 pneumonolyses.

Goorwitch[14] in 1944 reported a collected series including his own patients and comprising 5,114 patients. The incidence of pure tuberculous empyema ranged from 0 to 10 per cent (in one instance 24 per cent); that of pyogenic empyema from 0 to 6 per cent and mixed tuberculous empyema 0 to 5 per cent. The incidence of clinical success ranged from 44 per cent to 96 per cent and averaged 73 per cent.

Edwards, Penman, and Logan[15] in 1944 report that 133, or 66.4 per cent, of 200 patients with unilateral pneumothoraces with pneumonolysis survived five years and that seventy-one (86.5 per cent) of those with satisfactory collapse obtained at operation survived five years and fifty-six were well and working after six years. Tuberculous empyema was observed nine times and mixed empyema nine times but it accounted for only 18 per cent of the deaths.

H. A. Jones[16] in 1945 in a review of 509 consecutive closed intrapleural pneumonolyses over a seven-year period reports an incidence of only 1.5 per cent pure tuberculous empyemas, 0.4 per cent staphylococcus empyemas and 0.6 per cent mixed infection empyemas.

CLINICAL MATERIAL

During the period from 1940 to 1946 inclusive, 1,000 consecutive closed intrapleural pneumonolyses were performed upon 923 patients at the Herman Kiefer Hospital, Detroit, and the William H. Maybury Sanatorium, Northville Mich.

The distribution as to sex shows practically equal numbers in the white group and a slight preponderance of female patients among the Negro group. The ratio between the number of white and Negro patients is approximately five white to one Negro patient. The over-all fatality rate is 18 per cent. The fatality rate for the Negro group is 26.4 per cent and the white 16.3 per cent. In seventy-seven bilateral pneumonolyses there were sixteen deaths, or a fatality rate of 20.8 per cent.

The discussion of indications for pneumothorax does not fall within the scope of this paper. The indications for its use have been dealt with at length by Rafferty.[17] In this series there are no patients who were classified as having minimal disease, since it is our policy to treat such lesions with bed rest usually supplemented by phrenic nerve crushing. Also in many moderately advanced lesions which are noncavernous or in which cavities are small and thin-walled, we prefer an initial trial of a similar program. Consequently all patients have at least moderately advanced and the great majority have far advanced disease.

TABLE I. CLOSED INTRAPLEURAL PNEUMONOLYSIS: ANALYSIS OF 1,000 OPERATIONS EMPLOYED IN THE TREATMENT OF 923 PATIENTS (1940-1946)

RACE AND SEX	NO PATIENTS	DEATHS	FATALITY RATE (%)
White			
Male	380	66	
Female	379	59	16.3
Negro			
Male	65	19	
Female	99	22	26.4
Total	923	166	18.0
	BILATERAL PNEUMONOLYSIS		
White	68	14	
Negro	9	2	
Total	77	16	20.8

Since the immediate success of a pneumothorax would seem to be related most closely to the diseased lung which it collapses, we have found it convenient to classify the disease by extent, presence of cavity, and type of infiltration existing in the lung, and for the most part have ignored the standard classification of pulmonary tuberculosis.

TYPE OF DISEASE

The type of disease for which pneumothorax was initiated is shown in Table II. The presence of thirty-seven lungs with pneumonic disease is ac-

TABLE II. TYPE AND EXTENT OF DISEASE FOR WHICH PNEUMOTHORAX WAS INSTITUTED—1,000 LUNGS

PNEUMOTHORAX	NO.	PER CENT
Type		
Exudative	418	41.8
Mixed	250	25.0
Productive	295	29.5
Pneumonic	37	3.7
Total	1,000	100.0
Extent		
⅓ of lung	144	14.4
½ of lung	411	41.1
Over ½ of lung	445	44.5
Total	1,000	100.0
Cavity		
None	142	14.2
Under 2 cm.	396	39.6
2 to 4 cm.	340	34.0
Over 4 cm.	122	12.2
Total	1,000	100.0

counted for on the basis of urgency dictated by pulmonary hemorrhage or progressive disease. The indication for pneumothorax in this type of disease is admittedly very limited.

With regard to extent of disease it should be noted that one-half of the lung or over is involved in 86.6 per cent.

Cavities were present in 85.8 per cent of the lungs that were collapsed. Of these, 12.2 per cent were over 4 cm. in diameter, 34 per cent 2 cm. to 4 cm., 29.6 per cent under 2 cm.

In addition, there was contralateral disease in 80.6 per cent. Of the contralateral lungs there were 36.9 per cent with infiltration but no cavity, 19.6 per cent with cavity, 16.3 per cent with contralateral pneumothorax, and 0.6 per cent with thoracoplasty at the time of pneumonolysis.

POSTOPERATIVE COMPLICATIONS

The exercise of reasonable care at the time of operation should avert most of the dramatic complications which may occasionally occur. Experience alone is the best safeguard against too vigorous or too cowardly use of the cautery.

TABLE III. PLEURAL COMPLICATIONS, IMMEDIATE POSTOPERATIVE PERIOD

COMPLICATIONS	NO.	PER CENT
None	595	59.5
Fluid, serous		
Minimal, not aspirated	276	27.6
Large amount, aspirated	65	6.5
Fluid, hemorrhagic	46	4.6
Empyema		
Tuberculous	5	0.5
Mixed	4	0.4
Traumatic pneumothorax	8	0.8
Loss of space	1	0.1
Total	1,000	100.0

Careful closure of the wound and prompt adjustment of intrapleural pressures while the patient is still on the table should obviate troublesome subcutaneous emphysema, reduce cough and dyspnea to a minimum, and make effusion less likely.

The most common complication was simple fluid which developed in 276 instances or 27.6 per cent. This fluid was a trace in the costophrenic angle and in no instance rose as high as the dome of the diaphragm. In sixty-five instances there was sufficient fluid to warrant aspiration at least once and in some aspiration needed to be repeated often and continued intermittently until the lung was re-expanded. There were forty-six, or 4.6 per cent, of the operations which were followed by hemorrhagic fluid. In three instances the bloody fluid was so great in amount that transfusion was thought necessary. In one of these the chest was opened but bleeding was very minimal. A fourth patient, the second on whom thoracotomy was performed, perhaps unnecessarily, showed no active bleeding point. In both instances of bleeding where thoracotomy was done the fault was discovered to be in a change which the manufacturer had made in the cautery tip without our knowledge. All other hemorrhagic fluid was inconsequential.

Tuberculous empyema developed in five instances, or 0.5 per cent, and, in addition, in four others, or 0.4 per cent, there was tuberculous empyema with secondary organisms. Traumatic pneumothorax occurred eight times, or in 0.8 per cent. Two of these were fatal and will be described in more detail later. One space was lost. The immediate complications were all those which occurred any time within two months of the operation.

TABLE IV. EFFECT OF OPERATIVE SUCCESS UPON PNEUMOTHORAX

OPERATION	PNEUMOTHORAX IMMEDIATELY ABANDONED	PNEUMOTHORAX CONTINUED TO DEATH	LATER ABONDONED		EFFECTUAL PNEUMOTHORAX	TOTAL
			PLEURAL COMPLICATIONS	OTHER COMPLICATIONS		
Thoracoscopy only	33	4	10	7	25	79
Partial pneumonolysis	21	20	83	87	212	423
Complete pneumonolysis	11	31	71	70	315	498
Total	65	55	164	164*	552†	1,000

*1. Ineffectual Pneumothorax—Late.
2. Neglect by Patient.
3. Progression of Disease Elsewhere.
4. Inadequate Respiratory Reserve.
†120 Expanded—Therapeutically Sufficient.

Of the 1,000 lungs subjected to surgery, there were thirty-four two-stage operations and one three-stage procedure. The multiple procedures are considered as one operation in this analysis. As is shown in Table IV there were seventy-nine instances, or 7.9 per cent, where only thoracoscopy was performed. In this group the usual cause for failure was extensive adhesions. Seventy-one of the pleural spaces displayed adhesions which were extensively confluent or in which definite pleural symphysis was evident. In five other instances the pleural surfaces were inflamed and edematous, tubercles were noted, or the patient was too dyspneic to tolerate the procedure.

Partial pneumonolysis was performed in 423 or 42.3 per cent. Operations designated in this manner indicate that all adhesions were cut except those in which a small area of symphysis coexisted. Most often these areas of symphysis were located posteriorly in the costovertebral gutter or in the cupola or mediastinum. When adhesions were confluent with the mediastinal structures except for a lateral free border, the latter were usually cut to within 2 cm. of the danger area. Is case of doubt, when the vessels could not be well visualized, we cautiously abstained from severing adhesions in this area. In 309 instances the adhesions were extensive confluent bands, sometimes with only one free edge. Thirty-five showed at least a partial symphysis. In fifty-nine instances the adhesions were multiple discrete and in twenty instances minimal. In these latter two groups the accidental location of short adhesions in the region of the vessels was the only reason why only part of the adhesions could be cut.

Complete pneumonolysis, meaning the severance of all adhesions to the diseased lobe or lobes, was accomplished in 49.8 per cent of the cases. There were no cases of actual symphysis although eighty-five instances of extensive confluent adhesions were noted. The remainder were multiple discrete in 225 instances and minimal or solitary in 188 cases.

There were sixty-five pneumothoraces abandoned immediately after operation. Thirty-three of these followed thoracoscopy only, and twenty-one, or approximately one-third, followed partial pneumonolysis. Of the remaining eleven where pneumonolysis was complete, dyspnea, inflammation of the pleura, and tension cavity were responsible for the decision to expand the lung. One space was accidentally lost.

Effectual pneumothorax was the ultimate result in only twenty-five, or 31.6 per cent, where thoracoscopy only was done; in 212, or 50.1 per cent, of the partial pneumonolyses; and in 315, or 63.2 per cent, in those with complete pneumonolysis.

The reasons for abandonment of pneumothorax immediately following pneumonolysis were primarily related to ineffectiveness of collapse rather than to new pleural complications. Significant pleural complications were present in only ten of sixty-five cases. One was lost through disruption of the wound; two by traumatic pneumothorax; one from tuberculous empyema; one from hemorrhage and five from the development of large amounts of serous fluid.

To explain the reasons for failure this point has been studied in relation to type of disease extent of disease, and cavity size.

TABLE V. FATE OF PNEUMOTHRAX AFTER PNEUMONOLYSIS

TYPE OF DISEASE	PNEUMOTHORAX IMMEDIATELY ABANDONED		MAINTAINED TO DEATH	
	NO.	PER CENT	NO.	PER CENT
Exudative	30	7.2	22	5.3
Mixed	17	6.8	13	5.2
Productive	15	5.1	18	6.1
Pneumonic	3	8.2	2	5.4
Total	65	6.5	55	5.5

Table V indicates that the more active acute forms of disease are likely to lead to expansion early. The pneumonic group is so small as to be insignificant statistically.

TABLE VI. FATE OF PNEUMOTHORAX AFTER PNEUMONOLYSIS

EXTENT	PNEUMOTHORAX IMMEDIATELY ABANDONED		MAINTAINED TO DEATH	
	NO.	PER CENT	NO.	PER CENT
⅓ of lung	4	2.8	0	0.0
½ of lung	28	6.8	18	4.1
Over ½ of lung	33	7.4	37	8.3
Total	65	6.5	55	5.5

Considered from the angle of extent of disease, as in Table VI, we find, as would be expected, that early abandonment shows a more or less direct relation to this factor. The more extensive the disease the greater is the proportion of cases given up. In fact, the proportion of cases with involvement of over one-half a lung is more than two to one as compared to those who had lesions of one-third of the lung.

The most striking relationship is shown in Table VII where the existence of large cavity leads to failure approximately twice as frequently as in any other cavity group. Furthermore, it should be mentioned that the existence of cavity of any size doubles the chance of failure.

TABLE VII. FATE OF PNEUMOTHORAX AFTER PNEUMONOLYSIS

CAVITY	PNEUMOTHORAX IMMEDIATELY ABANDONED		MAINTAINED TO DEATH	
	NO.	PER CENT	NO.	PER CENT
None	4	2.8	5	3.5
Under 2 cm.	24	6.1	20	5.1
2 to 4 cm.	23	6.8	16	4.7
Over 4 cm.	14	11.5	14	11.5
Total	65	6.5	55	5.5

One of the most confusing issues in the reporting of the complications of pneumonolysis is that centered around the problem of empyema, admittedly the most serious of pleural complications. The definitions of tuberculous empyema range from the liberal one of Woodruff,[16] who includes all turbid fluids in the presence of pulmonary tuberculosis and any fluid containing tubercle bacilli on direct smear, and that of Eglee and Wylie,[19] who include only thick purulent fluid for which treatment is necessary. An even more strict conception is that suggested by DeCecio and Potter,[20] who include not only the presence of frank pus but also a clinical picture of rapid formation of exudate accompanied by prolonged fever and constitutional decline as the chronicity of the empyema is established. We have chosen an intermediate position and are in essential agreement with Goorwitch,[14] who interprets purulent fluid as an opaque fluid which is to be distinguished from serous fluid, described as clear, cloudy, turbid, translucent, or opalescent. Our definition of tuberculous empyema has been liberalized to include turbid or cloudy fluid which has required several aspirations and has persisted over a period of several weeks whether or not accompanied by fever or other constitutional symptoms. All such fluids were included which appeared at any time during the entire duration of the pneumothorax.

The coexistence of bronchopleural fistula with mixed empyema was proved to be present in the majority of instances and was assumed to be present in the remaining ones. Since obviously it also occurred in the traumatic pneumothoraces and was perhaps, at one time or another, present in some of the tuberculous empyemas, its total incidence is not clear and it does not appear alone in the statistics.

Persistent fluid is defined simply as serous fluid which occurred late in the course of pneumothorax following pneumonolysis which was consistently noted on fluoroscopic or roentgenographic examination or was aspirated on several occasions. It was most often unattended by constitutional symptoms. Frequently it was too small in amount to require aspiration.

It will be noted by referring to Table VIII that in 683, or 68.3 per cent, of pneumonolyses there were no late pleural complications. The inclusion of sixty-five immediately abandoned pneumothoraces and five immediate deaths in this figure is self-explanatory.

Traumatic pneumothorax occurred in five, or 0.5 per cent, and was responsible for death in two instances. Obliterative pleuritis with late loss of space resulted in sixty-three, or 6.3 per cent.

The incidence of tuberculous empyema occurring late is 3.5 per cent; that of mixed infection empyema is 1.5 per cent. The over-all incidence of empyema is 5.3 per cent since six instances of late empyema are also recorded as having their inception in the early postoperative period.

RELATION OF EARLY TO LATE COMPLICATIONS

The late complications listed in Table VIII obviously bear some relationship to those complications which occurred in the two-month postoperative period. For example, when late persistent fluid is considered we find that 35.4 per cent of those who had a large amount of fluid early show late persistent fluid; 26.4 per cent of those with a trace of fluid early had late persistent fluid; 23.9 per cent of those with hemorrhagic fluid early had late persistent fluid;

TABLE VIII. LATE PLEURAL COMPLICATIONS

COMPLICATION	NO.	PER CENT
None	683*	68.3
Persistent fluid	199	19.9
Empyema		
Tuberculous	35	3.5
Mixed	15	1.5
Traumatic pneumothrax	5	0.5
Obliterative pleuritis	63	6.3
Total	1,000	100.0

*Including five immediate operative deaths and sixty-five immediately abandoned.

and only 16.8 per cent of those with no fluid early develop persistent late fluid. Empyema, either tuberculous or mixed, persists in 66.6 per cent of those in which it was present in the early period. It develops in 18.5 per cent of the spaces where large amounts of fluid were present early; in 6.2 per cent of those with a trace of fluid, and in only 2.4 per cent of those with either no fluid or hemorrhagic fluid early. Late obliterative pleuritis is most marked in the early empyema group, being 11.1 per cent, and, in the patients with large effusions, 10.8 per cent. If hemorrhagic fluid, trace of fluid, or no fluid is present, then the rate of obliterative pleuritis is from 5.4 per cent to 5.9 per cent.

CAUSES OF DEATH

Of the five immediate deaths, one occurred the day of operation. This man had a contralateral pneumothorax in which there developed a tension pneumothorax. Furthermore he was a poorly controlled diabetic. The operation was on a minimal type of adhesion. A second death attributed to traumatic pneumothorax occurred on the fourteenth day in a Negro woman who had extensive bilateral disease. The three other deaths all occurred in individuals who had extensive bilateral acute disease. These individuals were febrile and had evidence of remote extension such as laryngitis and enteritis.

TABLE IX. PNEUMONOLYSIS—1,000 OPERATIONS ON 923 PATIENTS

CAUSES OF DEATH	NO.	
Immediate deaths		
Traumatic pneumothorax (contralateral lung) (24 hrs.)	1	
Traumatic pneumothorax (fourteenth day)	1	
Extension of tuberculosis (within 2 months)	3	
Total		5
Late deaths		
Traumatic pneumothorax	3	
Empyema—tuberculous 2 Mixed 5	7	
Extra pulmonary tuberculosis	8	
Pulmonary hemorrhage	4	
Extension of pulmonary tuberculosis	129	
Following thoracoplasty	4	
Chronic cor pulmonale	3	
Nontuberculous	3	
Total		161
Total deaths		166

The deaths occurring late could be attributed directly to empyema in seven instances, and to traumatic pneumothorax in three others. These deaths we feel bear close relation to the unwise use of pneumothorax and pneumonolysis. Of the remainder, extension of pulmonary disease is by far the most important cause of death.

PNUEMOTHORAX LATER ABANDONED

Of 164 who lost their pneumothoraces late because of pleural complications, 30, or 18.3 per cent, have since died.

Of the 164 patients who lost their pneumothoraces through their own neglect or because of inadequate respiratory reserve or extension of disease else-

TABLE X. PNEUMOTHORAX LATER ABANDONED

TYPE OF DISEASE	PLEURAL COMPLICATIONS		OTHER COMPLICATIONS	
	NO.	% TOTAL	NO.	% TOTAL
Exudative	74	17.7	69	16.5
Mixed	33	13.2	39	15.6
Productive	45	15.2	51	17.3
Pneumonic	12	32.4	5	13.5
Total	164	16.4	164	16.4

where or who were re-expanded late because of inadequate collapse, seventy-five, or 45.7 per cent, are now dead. Forty-one of the re-expanded group, either early or late, were subjected to thoracoplasty, thirty-seven primarily for the uncontrolled pulmonary lesion and four for obliteration of the empyema space.

TABLE XI. EFFECTUAL PNEUMOTHORAX

TYPE OF DISEASE	STILL MAINTAINED		REEXPANDED	
	NO.	PER CENT	NO.	PER CENT
Exudative	177	42.3	46	11.0
Mixed	120	48.0	28	11.2
Productive	126	42.7	40	13.6
Pneumonic	9	24.3	6	16.2
Total	432	43.2	120	12.0

One hundred twenty pneumothoraces have been re-expanded as therapeutically sufficient. Two in this group are now dead and four are still in the hospital. There are 432 patients with effectual pneumothorax of whom seventy are in the hospital because of the recency of institution of their treatment.

TABLE XII. PRESENT STATUS OF 923 PATIENTS SIX MONTHS TO SEVEN YEARS AFTER PNEUMONOLYSIS

TYPE OF DISEASE	LIVING AT HOME		IN HOSPITAL		DEAD		UNKNOWN	
	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT
Exudative	203	52.2	71	18.2	77	19.8	38	9.8
Mixed	121	52.2	46	19.8	42	18.1	23	9.9
Productive	164	61.9	33	12.4	41	15.5	27	10.2
Pneumonic	23	62.2	3	8.1	6	16.2	5	13.5
Total	511	55.4	153	16.6	166	18.0	93	10.0

Of 923 patients recent data are available on 830. In 483 the disease is arrested and in 181 it is still active. Five-sixths of the active cases are still in the hospital and though in many the disease is under control, it cannot be considered arrested.

TABLE XIII. PRESENT STATUS OF TUBERCULOSIS IN 923 PATIENTS SIX MONTHS TO SEVEN YEARS AFTER PNEUMONOLYSIS

TYPE OF DISEASE	ARRESTED		ACTIVE	
	NO.	PER CENT	NO.	PER CENT
Exudative	198	50.9	76	19.5
Mixed	114	49.1	53	22.8
Productive	149	56.2	48	18.1
Pneumonic	22	59.5	4	10.8
Total	483	52.3	181	19.6

DISCUSSION

Ideally, all pneumothoraces for which the original indications are sound should be converted to pneumothoraces entirely free from restraining adhesions if such a course is consistent with safety. Since for obvious reasons this is impossible of attainment, the choice between continuation of an ineffective pneumothorax and immediate abandonment in favor of some other measure often must be made. This decision will hinge mainly upon the appraisal of the pneumothorax as regards the possibility of severing adhesions. It is well known that the roentgenogram can be misleading and that thoracoscopic examination may be the only means of settling the issue. It is possible, however, to screen out certain cases from the roentgenographic survey alone. In this category can be placed pneumothoraces with widely adherent portions of the lung where separation is obviously impossible. Even in situations where advanced disease in the contralateral lung make impossible the use of thoracoplasty as an alternate procedure, the hazards are so great as to contraindicate pneumonolysis and in many instances even the introduction of the thoracoscope.

When there is reasonable doubt as to whether or not the adhesions are suitable for severing with the cautery, thoracoscopy should be done. If on inspection of the pleural cavity the adhesions are found to be simple bands, cords, or more complex arrangements of adhesions which present completely free borders on all sides and which do not attach dangerously near to important vascular structures, the indication is clear. If, on the other hand, inspection reveals a complex arrangement of adhesions which present only one or more free edges and then become confluent with the parietes, especially in the cupola or mediastinum, in such a fashion as to render complete severance unfeasible if not impossible, it is thought to be unwise to attempt cauterization of those portions available for section. In the range between two extremes of minimal or solitary adhesions and the situation related above, so much depends on the experience of the operator in determining the suitability of adhesions for section that absolute contraindications cannot be laid down. In general, however, it can be said that greater conservatism has run parallel with wider experience.

Obviously, however the suitability for operation cannot be decided solely upon the availability of adhesions for sectioning. Such factors as type of disease, extent of disease, cavity size and position are of paramount importance. Except for pneumonic disease in which perhaps the wisdom of the use of pneumothorax is open to question, and in certain extensive exudative lesions in which there is not actual lobar consolidation, there is no definite evidence to show any considerable difference in response following operation. It seems logical to conclude that following the initial phase of the disease when a higher incidence of pleural complications is to be anticipated from exudative and pneumonic disease there is a rapid conversion to a productive type of disease in which greater uniformity of response may be anticipated as regards pleural complications and eventual behavior of the lesion itself.

It is now well recognized and further confirmation is offered by the results of this study that a high incidence of pleural complications is to be anticipated in lesions with large cavities or multiple cavities of aggregate diameter exceeding 4 cm. The large cavity often fails to close even with free pneumothorax because of poor bronchial communication. Often even if such a lesion is apparently controlled, parenchymal damage is so extensive as to indicate permanent collapse or at least to make expansion hazardous, if possible. For these reasons it is questionable if pneumonolysis is ever justifiable in lesions with large cavity or cavities. When such cavities are definitely peripheral in position and are supported by dense adhesions it is considered an absolute contraindication to pneumonolysis.

CONTRAINDICATIONS

Briefly summarizing the foregoing discussion and adding certain generally accepted contraindications, the following are suggested as instances in which pneumonolysis should not be done.

1. In the presence of tuberculous empyema.
2. In the presence of acute febrile pleurisy with effusion.
3. When extensive progressive parenchymal disease is present.
4. When dense adhesions are present over large, peripherally placed cavities.
5. When pleural symphysis or extensive confluent adhesions make technical success very unlikely. (We do not believe that so-called enucleation of broadly adherent portions of lung by extrapleural dissection is a justifiable procedure.)

The following contraindications we believe to be relative because of the availability of thoracoplasty or other surgical measures as alternative procedures:

6. Unilateral apical fibrocavernous disease with extensive but apparently severable adhesions.
7. Wherever extensive parenchymal damage indicates the need for permanent collapse.

TECHNIQUE

The single cannula O'Brien Model (modification of original Cutler thoracoscope) with McCarthy foroblique telescope is used. The cannula is large enough to accommodate the telescope with a detachable cutting electrode. If the site of entrance is correct, it is nearly always possible to sever all the adhesions at one operation. High frequency spark gap current which can be switched from scalpel to cautery readily if bleeding occurs is always used. The tip of the cautery is in sight at all times except when it may be passed beyond an adhesion. The light is far enough removed from the lens to allow easy transillumination of adhesions. A side view or right angle telescope is available but rarely used.

Entrance into the chest is made by an incision parallel to the rib in whatever interspace is suitable (usually the third or fourth interspace in midaxillary line). The incision is usually 3 to 5 cm. in length and is carried through skin and subcutaneous tissues to the extracostal muscles. These muscles and the intercostals are split by blunt dissection and with the aid of small retractors the pleura is exposed. The pleura is punctured with the tip of a fine forceps which is held open until the cannula can be inserted through the opening. When the endopleural procedure is completed and the cannula removed, the intercostal muscles are carefully closed with a single figure-of-eight suture of No. 0 catgut or silk. The intrapleural pressures are always readjusted to the usual pressure by the removal of whatever amount of air is necessary to accomplish this. The usual case requires the removal of about 500 c.c. to 800 c.c. A small bandage is applied to the wound but no pressure binder is necessary. The patient is fluoroscoped daily. An effort is made to prevent the patient from lying on the side of operation for a week to avoid the possible formation of new adhesions.

The advantages seen for this instrument are as follows:

1. The ease of handling this simple compact unit makes a very tedious operation less fatiguing to the surgeon and consequently less hazardous to the patient.

2. The combining of the cutting electrode and telescope into one unit makes for greater accuracy of manipulation.

3. The high frequency electrosurgical unit of the spark gap type (Bovie electrosurgical unit) provides a very satisfactory cutting current allowing an adequate admixture of coagulating effect to the cutting blades, thus providing good hemostasis and still permitting ready and concise severance of adhesions. Postoperative edema and excessive eschar or coagulum on the cut stumps are minimal and, we believe, less than that seen when the galvanocautery is used.

A special ball type of electrode provides coagulation which is effective in controlling all but the serious hemorrhage which may occur as a result of accidental wounding of large vessels.

CONCLUSIONS

Pneumonolysis when employed by experienced operators in accordance with generally accepted indications may be performed without appreciable hazard to the patient and with the expectation that serious complications will be minimal. Its use in pneumothoraces which have been initiated to control small lesions and in which a few readily accessible adhesions are present should be attended by no serious complications. As the complexity of the adhesions increase, paralleling for the most part the increase in extent of the lesion, serious pleural complications must be anticipated with increasing frequency. The increase in incidence of complications to be anticipated under such conditions is the direct result of the necessity for prolonged tedious cauterization of difficult complex adhesion patterns. It is quite likely that the transection of small tuberculous foci or prolongations of lung into adhesions or within the adhesion itself is responsible for many pleural infections of tuberculous origin. In the more complex situations careful assessment must be made as regards the suitability of the lesion for other surgical procedures especially thoracoplasty. The latter is always preferable in unilateral disease when there is reason to expect persistent fluid and eventual empyema as a result of an extensive procedure. If, because of uncontrolled contralateral disease, unfavorable location of the lesion, or poor general condition, thoracoplasty is not feasible, extensive pneumonolysis may offer the only chance of recovery and may be justified even in the face of almost certain empyema. It is in this group of patients that the incidence of serious complications is likely to be high. Consequently a careful appraisal must be made in order to avoid performing needless operations which may result in increased morbidity and perhaps even in fatality which may be far out of proportion to the occasional therapeutic success. Indeed in many of these patients it is far better to abandon the pneumothorax and to allow them to live longer and without the discomfort and threat to life attendant upon pleural infection.

SUMMARY

1. Of 1,000 lungs treated with artificial pneumothorax in 923 patients for which pneumonolysis was attempted, the operation was complete in 49.8 per cent; partial in 42.3 per cent; and a failure in 19 per cent.
2. Pleural complications occurred more often and were more serious if partial pneumonolysis was done, less so if it were complete, and least in thoracoscopy.
3. Early postoperative complications were most frequent in face of extensive disease and least in minimal involvement. Early complications were most frequent if cavity was present and increased markedly with increase in cavity size. Also the more acute forms of pneumonic and exudative tuberculosis were associated with the highest proportion of complications.
4. Abandonment of pneumothorax in the early postoperative period was most frequently dictated by the condition of the collapse (success of pneumonolysis) and by the extent and character of the underlying disease.
5. Late complications tend to follow early ones, i.e., those with no complications develop proportionately the least in the late period. As each group of immediate complications increases in severity it tends to be followed proportionately by more frequent and severe late complications.
6. Late complications outnumber those in the early group and are proportionately more severe. These lead in one way or another to premature loss of pneumothorax in 32.8 per cent of the total.
7. Successful late pneumothorax is maintained in 432, or 43.2 per cent, of the group, and 120 additional, or 12.0 per cent, have been successful and are now re-expanded.
8. Five deaths occurred in the immediate postoperative period—two from the operation and three from extensive active tuberculosis.
9. One hundred sixty-one patients died later. At least ten of these deaths are thought to be due to complications more or less directly attributable to the operation.
10. Contraindications to pneumonolysis are discussed.
11. The technique of the single cannula method is described.

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DISCUSSION

DR. EDWARD S. WELLES, Saranac Lake, N. Y.—I am a little confused by the statistics, especially on the percentage of deaths.

I am not accustomed to associating death with pneumonolysis, and am afraid that this paper, if the figures are looked at lightly, is going to give the operation a black eye, not through the operations or the technique of the Detroit group, but through the analyses of their statistics, which I think are completely wrong.

On the first slide there was a 20 per cent death rate following pneumonolysis. A total of 161 died, so the mortality of pneumonolysis is 16 per cent.

That is ridiculous. I do not doubt that these people died, but they did not die from pneumonolysis, and there are several other factors that enter into this death rate. Undoubtedly a good many of these patients were dreadfully sick when pneumothorax was started, and might have died even if they had not had pneumothorax. Possibly some of them who are described as having exudative acute disease might much better have been left alone until they quieted down, and probably a good many of them might better have been given primary thoracoplasty and not pneumothorax at all. It was not the pneumonolysis that killed them.

Maybe the five immediate operative deaths come in there, and maybe some of the later ones could be attributed to the operation, but I cannot believe such figures. An explanation ought to be made in the paper itself when it is published, because I have been doing pneumonolysis for 21 years, and am afraid that people reading this paper, who are not here to hear this discussion will get the wrong impression. I would hate to have them frightened away from as harmless an operation as pneumonolysis by thinking of a 16 or 20 per cent death rate following the operation.

One other little point: one of the contraindications to the operation, I think this is straight, but I am not sure, is peripherally placed cavities. That I do not understand, either, because in a great many of the pneumothorax cases which require pneumonolysis there are peripheral cavities. As soon as the bands are cut and the cavities are released, they are closed, and I do not understand this as a contraindication.

DR. JULIAN A. MOORE, Asheville, N. C.—I agree with Dr. Welles. I thought that mortality rate of 16 per cent was tremendous. If I felt that my mortality were going to be 16 per cent with this operation, I would have abandoned it long ago.

It seems to me unfair to the procedure to give the late mortality rate of tuberculosis and not of the operation. The actual mortality from the operation, both directly and indirectly, was fifteen patients out of 1,000, which is 1.5 per cent. This corresponds closely with what has been reported in the literature before.

Now the operation was designed for one purpose, and that was to convert an unsatisfactory pneumothorax into a satisfactory pneumothorax, and if you succeed in doing that, as far as the technical procedure is concerned, the operation is successful. The results and the complications from then on are those of pneumothorax, and I do not think that the operation, per se, greatly increases the complications of pneumothorax without pneumonolysis. This certainly has not been my experience.

I am not prepared to give any figures on pneumothorax, but all of you know that pneumothorax has certain complications inherent in the procedure itself. They are both immediate and late. There are also many failures of pneumothorax to close a cavity when there are apparently no adhesions whatsoever.

The question of the technique of this operation depends upon the individual preference of the operator.

I remember very distinctly that thirteen years ago Dr. O'Brien said it was a terrible operation, and until he designed his own instrument which was satisfactory to him, it was awful. I happened to be one of those who designed an instrument that is satisfactory to me, and I do not believe Dr. O'Brien is as ambidextrous as he looks to be when he does a thoracoplasty.

DR. LOUIS R. DAVIDSON, New York, N. Y.—I do not intend to repeat what both Dr. Welles and Dr. Moore have already stated to you. Dr. Day's presentation was well catalogued but his interpretation, perhaps, has been incorrect. There are just a few points I should like to make.

Eighteen years ago I happily devised the first commercially produced single cannular thoracoscope and, in my state of ignorance, was quite pleased with it. At that time Dr. John Alexander said to me, and I disagreed with him, ''You are merely looking about and have a prehensile hand at your forehead.'' In that I described this instrument and its virtues, I owe it to the profession, now that I have abandoned the instrument, to tell them so and the reasons why I have gone over to the double cannular technique.

I believe one of the reasons why Dr. O'Brien and his group do not disinsert adhesions, thereby limiting the opportunity of many patients, is that they still use a single cannular instrument. All of these single technique devices limit the field of vision. In addition, the manipulation of the instrument in the field of the attachment of the adhesion is narrowed. Endothoracic disinsertion cannot be performed. In this connection I recommend the paper of Dr. August Maurer which appeared about fourteen years ago in Brauer's *Beitrage*.

In general, an x-ray does not tell you which patients can, and which cannot be operated upon. Only when one looks into the pleural space, and then sometimes with difficulty, can he tell which adhesions can be severed or disinserted.

The A.C.M.I. is coming out with a new, improved instrument which is devised by Dr. Irving Sarot. It has a magnificent field of vision and is of the double cannular type. It is basically the original Jacobeus instrument with modifications permitting easier manipulation and surer surgery.

I firmly feel there is only one type of instrument to be used in the Jacobeus operation notwithstanding the fact that eighteen years ago I very specifically advocated the single cannular instrument. Only with the double instrument can disinsertions be safely performed.

In addition, the field of vision is more extensive. Finally, I should like to say that with a double cannular instrument the complications are fewer and that is because the pathology is more exactly and distinctly visualized.

DR. E. J. O'BRIEN, Detroit, Mich.—Dr. Day, I think, expressed very clearly at the start of his paper that he thought it was wrong to evaluate the earlier and not the end results following lysis. We wanted to know what happened to these patients. There were a thousand of them done during the period from 1940 to 1947 and a large number before, but we wanted to know the eventual outcome of the treatment with our present technique.

Naturally this operation is in combination with pneumothorax and every time I think of pneumothorax I think of a Boston bull I used to have. He was a wonderful dog when he started out, but he started to develop messy habits, and got so bad we had to shoot him. That is about the way with pneumothorax, unwisely started and continued after complications arise. If pneumothorax alone becomes unduly messy it follows that this procedure with added lysis can be expected to come to the same bad ending if carried on blindly.

We wanted to know whether we had been right in doing these pneumonolyses or whether we should have done more and more thoracoplasties; I think the statistics given in this paper will warrant the conclusion that we should have. We are now doing many more thoracoplasties and quite frequently do a primary one without attempting pneumothorax at all.

Dr. Day also showed that our bad results were in direct proportion to the extent of the disease. That is why we hesitate to cut extensive adhesions, overextensive disease, but would prefer to give up the pneumothorax and do a thoracoplasty.

Drs. Davidson and Moore have apparently missed a good bit of the paper. We do not admit a high mortality from the procedure itself, but have shown what happened to those patients later on. The paper made that quite clear. You do a pneumonolysis on a patient because you want him to get well not just to survive the operation. We have told you how many became well and how many had trouble, and what the trouble was. I think our interpretation of empyema was a very broad one—anything from a little cloudy fluid, upward. Those papers that present lower figures on this complication are often open to question, because it is the individual's own interpretation of empyema.

I do not know just how Drs. Davidson and Moore have come to the conclusion that their instrument is better than mine, or mine is inferior to theirs. They have not seen mine. Now the scope that Davidson is talking about—I tried that too—that is why I wrote the article on open pneumonolysis years ago. I could not see anything through it. You can see with our scope, and you can cut any adhesion that can be cut with any other instrument. Why you should use the chopstick method of Jacobaeus or its modifications, I would not know.

DR. J. CLAUDE DAY, Detroit, Mich.—Perhaps the figure showing the fatality rate is somewhat *misleading. It does not mean operative mortality. It refers simply to the percentage* of the entire group of patients who died from any cause at some time during a period of observation of from six months to seven years. The operative fatality is clearly indicated.

We have not discussed the indications for pneumothorax though we are well aware of their close relationship to the indications for pneumonolysis. The latter are predicated on an original sound indication for pneumothorax.

It is not our intention to indicate that pneumothorax was used as a measure of choice in acute exudative and pneumonic types of disease. We are in agreement with the majority of opinions that pneumothorax is contraindicated in such lesions except for the occasional instances in which it is used to control pulmonary bleeding.

As regards the type of instrument, we prefer the single portal of entry with the combined cautery and telescope in one unit. It is quite likely that with experienced operators the results will be much the same regardless of the type of thoracoscope used. We do feel, however, that the original Davidson-Cutler thoracoscope is wholly inadequate to the task and indeed is dangerous because of the extremely limited field of vision afforded. We used it before Dr. O'Brien's modification was available and were never satisfied with it.

My experience with the double portal type of instrument of the Coryllos type while in the Navy, though not large, was sufficient to convince me of the superiority of our type of thoracoscope.

Several instances could be cited of men who were trained to use the Jacobaeus method and who since have had the opportunity to use ours. They have indicated a preference for the latter.

Though we are not in a position to prove it statistically, it is our feeling that the electrosurgical method has many advantages over the galvanocautery and should be used even though a separate trocar wound is used for its introduction into the chest.

We feel definitely that in large peripherally placed cavities suspended by dense adhesions, pneumonolysis is contraindicated. The occurrence of large bronchopleural communications as a result of necrosis of cavity walls with the development of rapidly fatal severe pleural infections is familiar to all. Such a disastrous sequence occurring soon after operation readily establishes the causal relationship of the latter. However, the establishment of late fistulous communications at a more remote period following operation does not indicate that the pneumonolysis can be exonerated completely as a causal factor. In view of the high incidence of pleural complications to be anticipated in these lesions and of the difficulties often encountered in effecting closure, if pneumonolysis does provide a free space, we have felt that the indications for pneumothorax and pneumonolysis should be appreciably restricted.

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PRELIMINARY ANTERIOR CHONDROCOSTECTOMY COMBINED WITH CLOSED CAVITY DRAINAGE AND POSTERIOR THORACOPLASTY

Edward S. Welles, M.D., Saranac Lake, N. Y., and
Joseph Gordon, M.D., Ray Brook, N. Y.

THE problem being considered is collapse of large or so-called giant tuberculous pulmonary cavities. Among thoracic surgeons it is accepted that thoracoplasty is still the most satisfactory method of treating advanced tuberculosis. During the past several years a large amount of work has been done on lung resection. For a while it seemed that removal of a diseased lobe, or the whole lung, might be a better way of treating the disease and that resection might supplant thoracoplasty as the operation of choice. As more reports have come in, giving the immediate and especially the late results of this treatment, early enthusiasm has changed. The majority of the members of the American Association for Thoracic Surgery seem to be in agreement that resection should be reserved for certain types of cases or used when thoracoplasty has failed. In the usual case for surgical collapse with one or more moderate-sized cavities, thoracoplasty results in their closure and sputum conversion in a high per cent. However, in the past many years, it has been found that in these giant cavities, though greatly reduced in size by thoracoplasty, a small triangular or slitlike remainder persisted when the operation was finally completed. Despite this, the patient was very apt to make a satisfactory recovery and become clinically well except for the fact that he still raised a certain amount of positive sputum.

In 1927 one of us (E. S. W.)[1] described an accessory anterolateral operation done through an axillary incision. After failing to close large cavities completely with the standard posterior thoracoplasty, removal of remaining anterior segments of ribs and parts of costal cartilages, sometimes succeeded in closing these cavities. As time went on, it was found that this *accessory operation usually further reduced cavity size but did not close it,* and therefore failed to convert the sputum. Revision operations in our hands have been found difficult and dangerous, and also failed to close remaining cavities in a large percentage of cases. Serious thought has been given over the last several years to this problem of the uncollapsible cavity which was described somewhat pessimistically by one of us (E. S. W.)[2] in 1936.

After variable experience with Monaldi cavity drainage, which in the majority of cases did not work alone, it seemed that if it could be combined with thoracoplasty, the desired result might be obtained. Here, however, a technical difficulty arose. If the Monaldi tube were inserted anteriorly into the cavity through the first or second interspace, the tube might be encountered

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during posterior or anterior thoracoplasty and serious wound infection would result. A plan was therefore devised to precede cavity drainage by a preliminary anterior stage in which the cartilages of the first three ribs were removed along with bony portions to about the midaxilla. The Monaldi tube could then be put in and the posterior thoracoplasty done without coming in contact with the tube.

With this plan in mind, operations on the first few cases of giant cavity were started. The technique of anterior thoracoplasty is not new, it was described by Wangensteen[3] and was also illustrated in Alexander's book (1937).[4] Following the anterior stage a distinct diminution in the size of the cavity was seen. As this plan was tentative and experimental, it was decided to go ahead with the first posterior stage before putting in the tube. There followed such marked collapse of the cavity that it was decided to postpone drainage once more and do the second posterior stage. In the first six cases done by this method complete closure of cavity resulted, and it was felt that the answer had been obtained. Disappointment followed, however, and the next case that was done resulted in the old type of failure. A long, cigar-shaped cavity was left which continued to produce a large amount of sputum. It was decided to put a Monaldi catheter into this remaining cavity and apply suction. Unfortunately, it was found that this could not be done. Two attempts were made to introduce the catheter but the cavity was so narrowed and lying so close to the aorta that both attempts had to be abandoned. Since that time a number of cases have been done by following the original plan. The drainage tube has been inserted about ten days to two weeks following the anterior stage. Suction has been started and two weeks or so later the posterior stage has been done and others followed in regular order, as needed. Thus far, all of these patients have obtained cavity closure. In some the tubes have already been removed, the sinus tracts have healed, and the cavities thus far have remained closed. Others are still on suction. It is hard to decide just how long the tube should be left in. Probably when the drainage becomes very scant, the bronchial fistula closed, and no evidence of cavity can be seen in x-ray examination, the tube should be removed. It would be preferable if all of these patients could be treated without Monaldi drainage. Introduction of the tube, if done when the cavity is still large, is usually simple and easy. The aftercare of the tube and the suction apparatus is a considerable nuisance to the patient and the nursing staff. We can see no way of predicting which cases will close without Monaldi drainage and which will fail. If one guesses wrong and waits until failure has occurred to put in the tube as a last resort, it may be impossible to do so.

Several incisions and approaches have been previously described for the anterior thoracoplasty and were given in detail by Alexander.[4] It is believed that the incision employed here gives maximum exposure for the removal of the first three cartilages to the sternum. A curved incision is used extending from the sternal end of the first rib, across the second cartilage, along the second interspace, and upward to the axillary fold (Fig. 1, A).

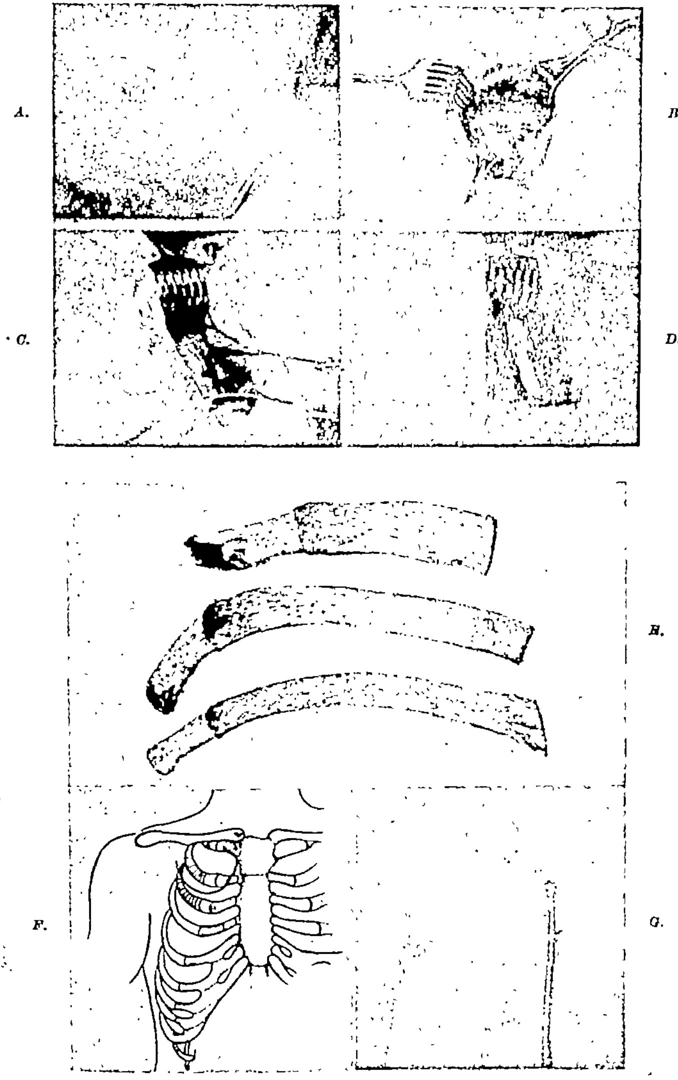


Fig. 1.—*A*, Showing line of incision. *B*, Showing pectoralis major muscle retracted after being divided in direction of fibers and pectoralis minor muscle retracted laterally, exposing second rib. *C*, Showing perichondrium partially peeled from cartilage. *D*, Showing rib freed of both perichondrium and periosteum, ready for resection. *E*, Lengths of resected ribs. *F*, Schematic drawing showing curved line of incision. Dotted area showing extent of resection by Wangensteen and co-workers. This, plus hatched area of first three ribs, but none of fourth rib are removed through incision shown. *G*, Photograph showing healed incisional scar and drainage tube in situ.

The pectoralis major muscle is split in the direction of its fibers, and the pectoralis minor muscle retracted laterally (Fig. 1, B). Resection is begun with the second cartilage. Because of its intimate attachment and thickness, the perichondrium is best "peeled" from the cartilage rather than scraped off. The perichondrium is incised in the axis of the rib, care being taken not to cut too deeply as the cartilage will chip and make removal of the

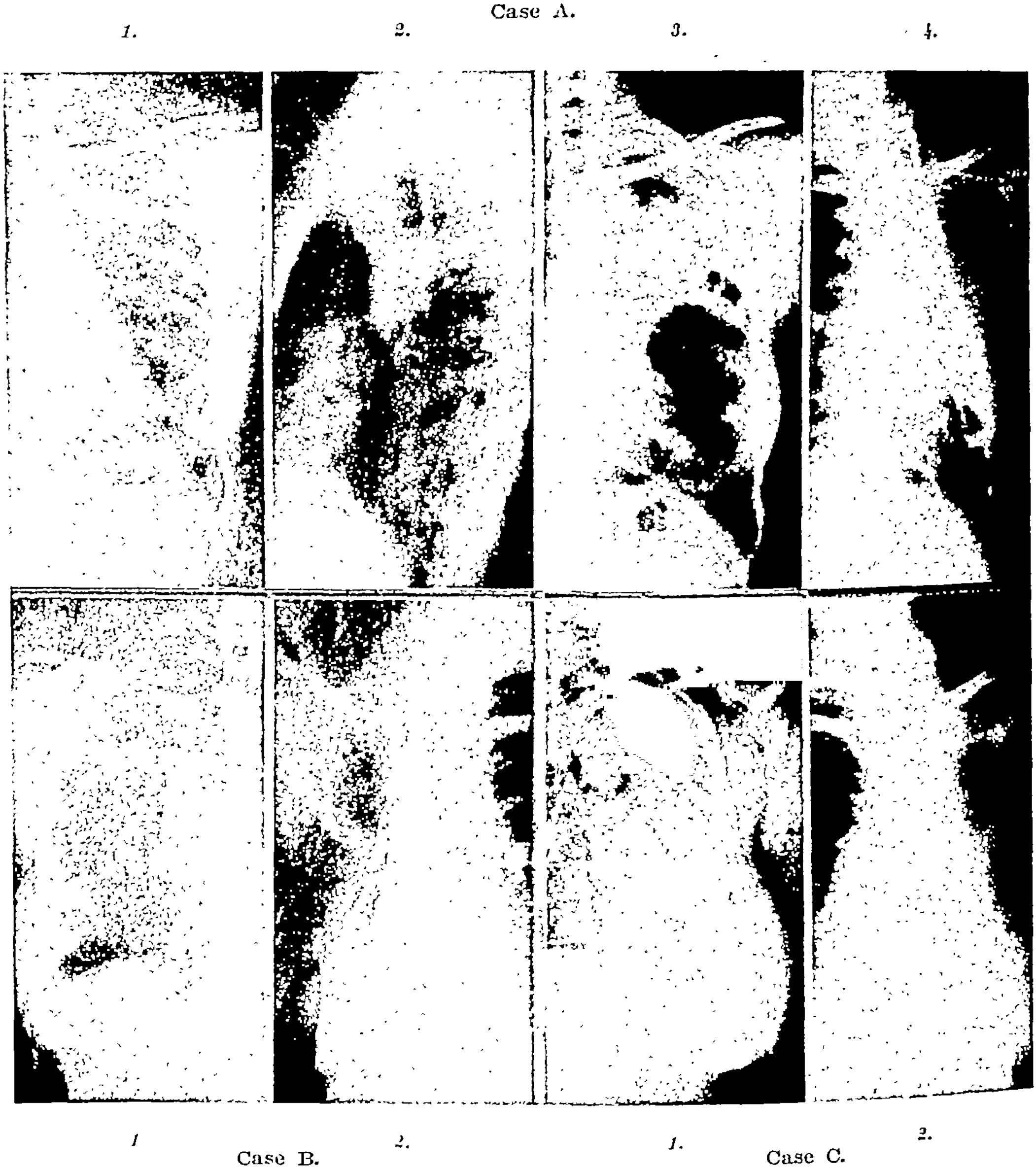


Fig. 2.—Case A, Treated without cavity drainage. (*1*) Preoperative posteroanterior film showing giant cavity in left lung. (*2*) Preoperative left lateral film showing giant cavity in left lung. (*3*) Following anterior thoracoplasty some decrease in cavity size. (*4*) Film showing completed thoracoplasty; patient asymptomatic and sputum negative; discharged.

Case B, Treated without cavity drainage. (*1*) Preoperative posteroanterior film showing giant cavity and extensive disease in right lung. (*2*) Postoperative film, surgery completed; patient clinically well and sputum negative; discharged.

Case C, Treated without cavity drainage. (*1*) Preoperative posteroanterior film showing giant cavity and completely useless left lung. (*2*) Postoperative film, surgery completed; clinically well, sputum negative; discharged.

perichondrium difficult. Near each end of the cartilage a transverse incision is made to facilitate lifting the perichondrium with a blunt-ended elevator (Fig. 1, C). After the cartilage has been freed of perichondrium the remaining bony segment to the midaxilla is scraped free of periosteum (Fig. 1, D) and the rib sectioned in the usual manner. Segments of the first and third ribs are then removed in that order. It is *only occasionally possible to remove*

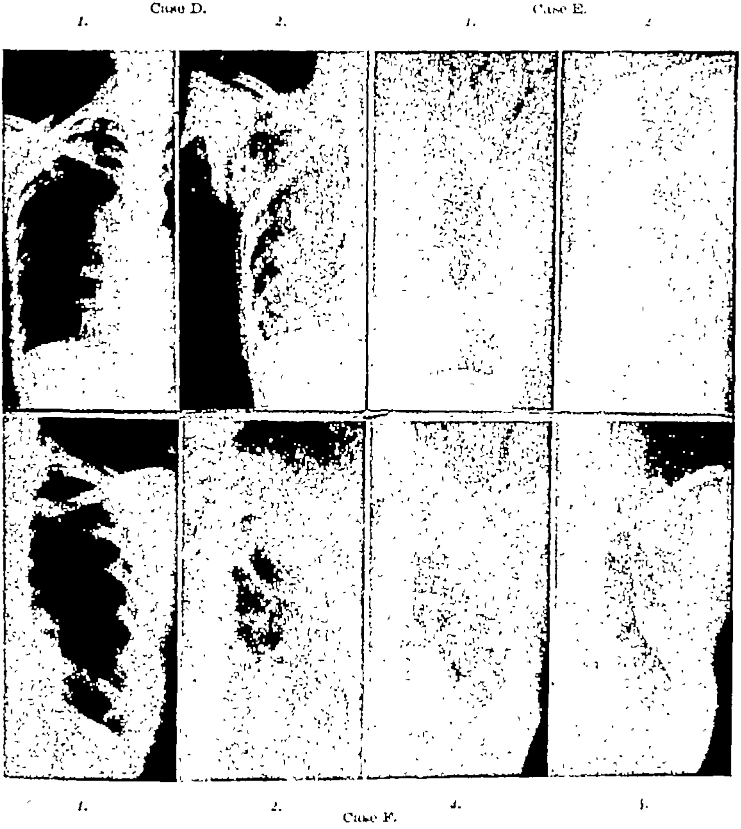


Fig. 3.—Case D, Treated without drainage. (*1*) Preoperative film showing large cavity, and disease through right upper lobe. (*2*) Postoperative film, surgery completed, patient clinically well, sputum negative.

Case E, Treated without drainage which was attempted after failure of cavity closure. (*1*) Preoperative film showing giant cavity and extensive disease in left lung. (*2*) Postoperative film showing residual cavity slit adjacent to aorta.

Case F, Treated with drainage after anterior and first posterior stages. (*1*) Posteroanterior film showing giant cavity. (*2*) Posteroanterior film following anterior and first posterior stage, cavity little changed. (*3*) Film following introduction of drainage tube and cavity markedly reduced. (*4*) Film after surgery completed, tube removed, sinus healed; patient well, sputum negative, and working part time as nurse.

the first rib intact (Fig. 1, E). Most often, it is best removed piecemeal with a small rongeur after stripping perichondrium and periosteum from it. The sternal marrow is regularly exposed at this time. It is common to see a freely moving lung beneath the pleura, as most of the disease is in the posterior part of the lung. Great care must be exercised to avoid injury

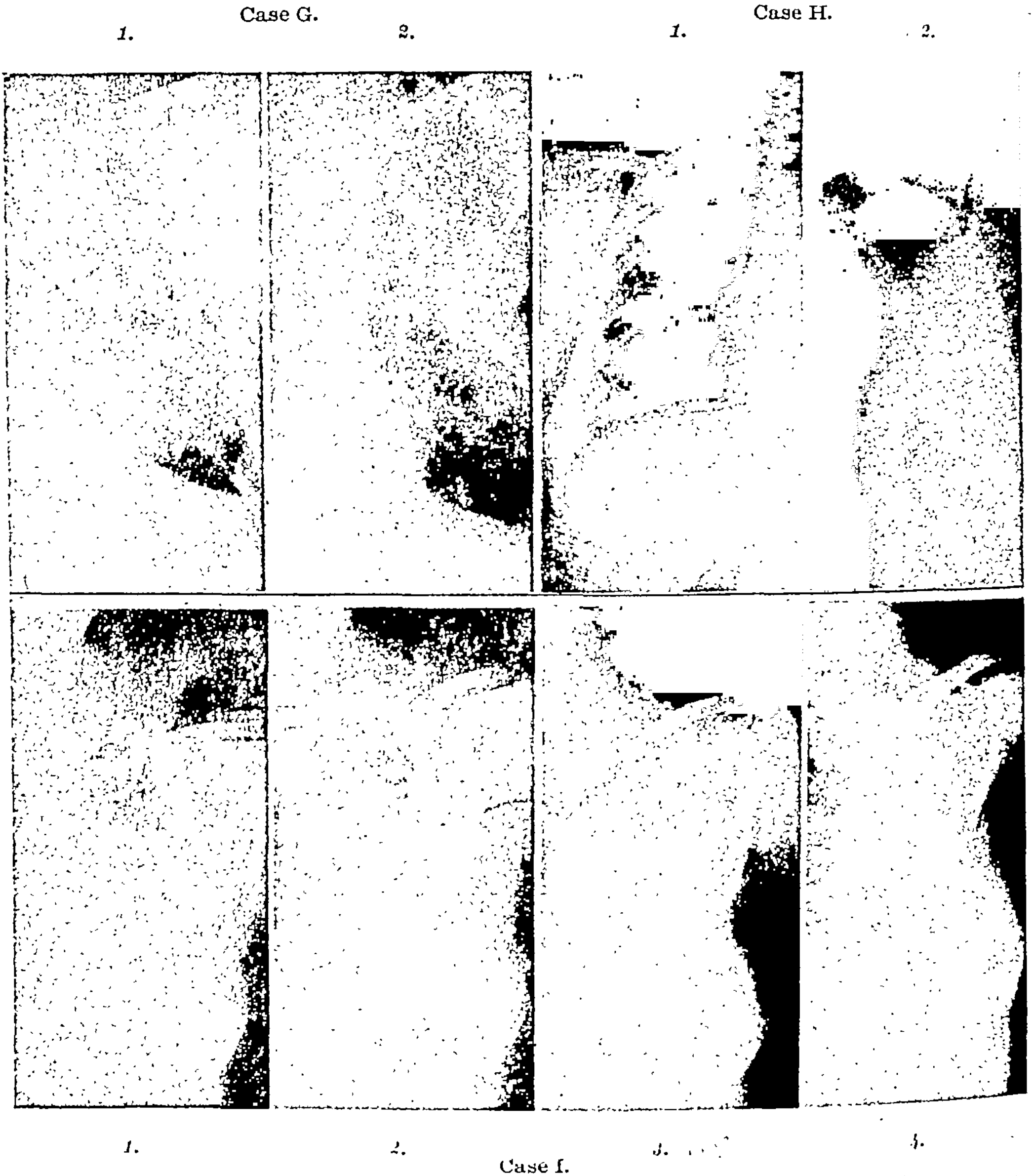


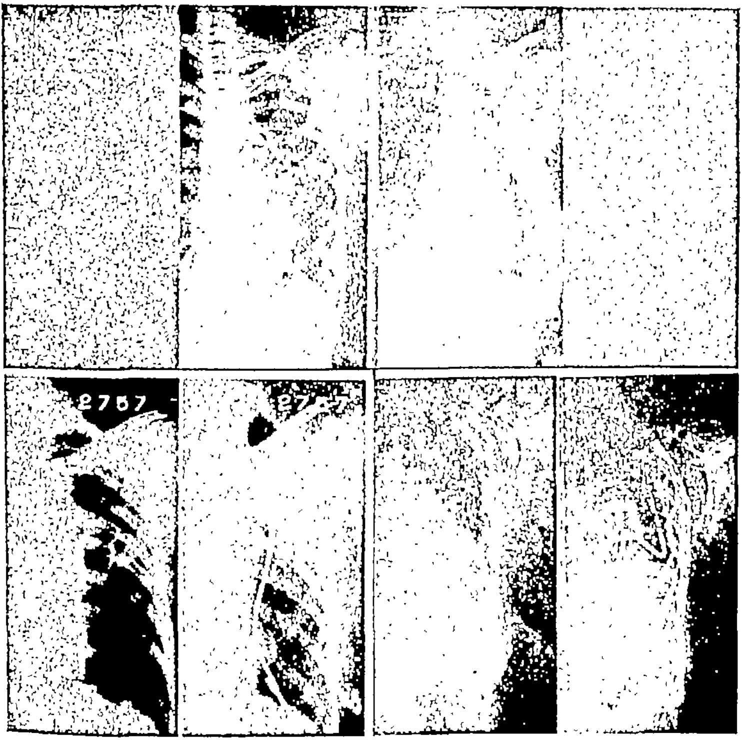
Fig. 4.—Case G, Treated with drainage. (*1*) Posteroanterior film showing giant cavity and extensive disease in left lung. (*2*) Postoperative film, surgery completed; patient asymptomatic, no sputum raised; postoperative convalescence being completed (note slitlike shadow is not cavity).

Case H, Treated with drainage. (*1*) Preoperative film showing giant cavity. (*2*) Postoperative film, surgery completed, catheter removed, sinus tract healed; patient clinically well and completing postsurgical convalescence.

Case I, Treated with drainage. (*1*) Preoperative film showing giant cavity, useless lung, and evidence of previous operation by regenerated ribs; Maximum breathing capacity 43 liters. (*2*) Film after anterior stage (first two ribs) and cavity drainage established. (*3*) Film after first posterior stage (first two ribs), catheter nonopaque. (*4*) Film after completed surgery, catheter removed, sinus healed, patient clinically well, sputum negative; completing convalescence.

to this tissue-paper thin pleura. Rib resection should be back far enough, not only to facilitate the posterior stage, but also to avoid the cavity drainage tube which will have been previously introduced between stages. The wound is drained with a Penrose tube and closed in layers. A firm, compressive dressing is then applied to aid in limiting paradoxical movement of the chest. The drain is removed in forty-eight hours.

Case J.
1. 2.



1. 2.
Case K.

1. 2.
Case L.

Fig. 5.—Case J. Treated without drainage. (1) Posteroanterior film showing giant cavity. (2) Postoperative film surgery completed, patient clinically well; discharged and working as housewife.

Case K. Treated with drainage. (1) Preoperative film showing giant cavity and extensive disease through left lung; patient acutely ill. (2) Film following anterior stage, cavity drainage and one posterior stage; cavity reduced to slit, patient markedly improved; surgery to be completed.

Case L. Treated with drainage. (1) Preoperative film, showing giant cavity, useless left lung; patient acutely and seriously ill. (2) Film following anterior stage and cavity drainage, marked reduction in size and great symptomatic improvement.

The posterior stage is greatly facilitated, and after stripping the remaining posterior segment of rib of its periosteum and sectioning it from behind, the anterior end is freed by simply lifting it out. Frequently, a segment of the fourth rib is removed at the first posterior operation. Extrafascial or extrapleural apicolysis is not employed, but the first and second intercostal muscle bundles are routinely severed posteriorly and allowed to drop down over the collapsing lung. The anterior chest wall has, in each instance, developed sufficient stiffness postoperatively so as not to be a problem in paradoxical movement.

The patients all had far-advanced disease according to the National Tuberculosis Association classification. The distribution was most often bilateral and it was perferred to have the contralateral disease in the quiescent or stable phase. All had positive sputum and many raised copious amounts of thick, purulent secretions. A number had bronchial disease, as noted by bronchoscopy. Though studies of respiratory reserve were not often made on these ill patients, it was estimated clinically that adequate functional pulmonary reserve was present considering the extent of lung to be collapsed. The anterior operation was well tolerated because of minimum blood loss, absence of any shock, and minimum of tissue trauma. For this reason the older aged group (sixth decade and over) was similarly treated without cavity drainage.

Some very sick patients for whom in the past thoracoplasty was considered too hazardous have been operated upon by this plan. With the establishment of cavity drainage and all of the previously reported advantages of the Monaldi operation (diminished expectoration, reduction of fever, general symptomatic improvement), it has been possible to carry these patients through their thoracoplasty operation. In dealing with such a poor type of case, a certain mortality must be expected. However, in reviewing the few patients who have died, it would seem that in each instance we were overenthusiastic in accepting them for surgery. A statistical analysis is not given at this time because (1) the series is too small for significance and (2) the follow-up period is too short. It must be stated, however, that the results thus far obtained warrant the further use of this plan. It was originally planned to give a brief summary of a number of typical cases at this point, but the illustrations speak for themselves and the clinical histories are omitted.

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DISCUSSION

DR. W. A. HUDSON, Detroit, Mich.—In 1931, I presented before this group what I termed an anterior stage thoracoplasty, to be done as a primary procedure in the management of giant cavities, giving what I thought, at the time, were acceptable reasons for doing the anterior stage.

We demonstrated the extent or length of the rib that can be removed and the marked collapse of these giant cavities that can be obtained by the resection of a limited number of ribs, anteriorly. It is possible, at an anterior operation, to remove the complete length of the first and second rib, disarticulating them at the corresponding transverse vertebral processes.

Since 1931, we have made the anterior stage the first operation to be done in a majority of the thoracoplasties, which we have done. We have found that the collapse is much more satisfactory, and we are permitted to limit the thoracoplasty to a fewer number of ribs when we undertake to do the posterior resection.

Now, in the cases that Dr. Welles has presented, I am impressed by two points: (1) Some of the giant cavities that he is dealing with are, I am convinced, tension cavities, and if the tension could be relieved, the magnitude of the cavity would, of course, be reduced. (2) A decision should be made as to whether or not one can anticipate a satisfactory closure of the cavity by the thoracoplasty without further intervention, or whether it will be necessary to introduce a tube in order eventually to obliterate the cavity. In those cases in which it is thought that it might be possible to close the cavities and convert the sputum by the thoracoplasty, I would perfer that the first stage anterior thoracoplasty be followed by the routine posterior resections, but in those cases in which suction drainage is contemplated, I would prefer to introduce suction, following later with a cavernostomy.

Dr. Welles has told us that he has not removed the tubes in all of these cavities. He says that he thinks eventually he can remove the tubes, and hopes that they will be all right.

At one of the meetings, soon after suction drainage was first introduced in this country, it was brought out that the cavity would, in a great percentage of cases, become reinfected because of contamination through the open bronchus, and open up again. In most such cases, in my own hands, they have required secondary operations at some later date because of reinfection of the residual cavity. I think the giant cavities that have been treated by suction should be cleaned up by a cavernostomy, something of the type that was presented at this meeting last year.

The incision that Dr. Welles has exhibited is a little different from the incision I have used. The line of the incision that I use extends from a point just medial to the head of the humerus and downward and medialward to the junction of the second costal cartilage with sternum. This affords ample exposure for a generous resection of the ribs.

Dr. W. L. Rogers, San Francisco, Calif.—I believe this subject is important to all of us dealing with tuberculosis.

Dr. Welles has combined the two principles of decompression with external drainage and extensive apical collapse.

In view of the fact that in this particular group of cases under discussion the amount of caseation and fibrosis of the lung parenchyma is usually minimal, and bronchial disease may be playing an important role in maintaining the large cavity, we have of recent date used streptomycin preoperatively and postoperatively in conjunction with collapse therapy. Our results to date have been encouraging, and we hope this combination may obviate at least to some extent the necessity of cavity decompression and drainage either initially or later.

We all appreciate, I am sure, before evaluating surgical procedures for tuberculosis, especially in the presence of tension cavities, that considerable time must elapse before final evaluation may be made.

I would like to ask Dr. Welles if they supplemented streptomycin therapy in this group under discussion either systemically or locally into the cavities after drainage had been established.

DR. WARRINER WOODRUFF, Saranac Lake, N. Y.—I should like to substantiate what Dr. Welles has said. However, this is not an entirely new procedure.

Three years ago, before the meeting in Chicago, Dr. Head presented a paper on intracavitary (Monaldi) suction, and he gave as one of his indications, the reduction in size of extremely large excavations as a preliminary to thoracoplasty. It is this group that Dr. Welles has discussed today.

At that time we reported six instances of Monaldi followed by thoracoplasty. Since that time, Kelley, Merkel, and I have had an additional twelve. We have several others where Monaldi suction has been done and we hope to follow with thoracoplasty.

There is one point that Dr. Welles has made in the abstract—and again this morning—which I think is most important to get closure of the cavities, namely, do not wait until after the anterior ribs have regenerated before starting a posterior stage. Unfortunately, we have done that in several instances. Many of the candidates for Monaldi suction are so ill that thoracoplasty seems inadvisable. Sometimes it is only after months of drainage that they are in condition for thoracoplasty and by then rib regeneration has occurred. This has been a cause of failure to close cavities with us, so I urge that the posterior stage be done as quickly as possible following the insertion of the catheter.

The other point which I think is very important, as Dr. Welles brought out, is the extent of ribs which it is necessary to take anteriorly. The longer the anterior length, the better the original collapse, and the less likelihood of breaking into the sinus tract at the posterior stage. We have had one instance where, at the posterior stage, we opened into the sinus tract, with the catheter in place. We closed the wound and left the catheter in place, and no infection developed. We and the patient were very fortunate.

In some instances where the anterior section was not long enough, we have even left a small section of the rib anteriorly, just to avoid breaking into that sinus tract.

DR. EDWARD S. WELLES, Saranac Lake, N. Y.—I should like to say to Dr. Hudson that our experience with cavernostomy has not been very pleasant, and we like to do anything to avoid it.

He said that some of the tubes are not yet out, and asked if the cavities remain closed, when they do come out. I do not know, except that in all the ones that we have finished to date, from which we have taken the tubes, the cavities have remained closed, and the sinuses have healed.

I think with the combined thoracoplasty, on top of the tube, when we take it out, the cavity will close and not reopen the way the old Monaldi type did, which did not have a thoracoplasty.

Streptomycin has been used for some of these patients preceding and along with the operation, and some of them are taking it right now. We have not instilled streptomycin into the cavities. On the contrary, we have taken it out. That is we have taken cavity drainage in a bottle to the laboratory and had it tested, and found plenty of streptomycin in it. So as long as it is coming into the cavity from the inside, we have not put any in from the outside.

Erratum

In the article by Sommer, Jr., and O'Brien entitled "War Wounds of the Esophagus" in the June, 1948, issue of the JOURNAL, Figs. 1 to 4 should be assigned to Case 2 rather than to Case 1.

The American Association for Thoracic Surgery

1948-1949

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REPORT OF MEETING OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

May 31, June 1 and 2, 1948

THE twenty-eighth meeting of the American Association for Thoracic Surgery was held in Quebec, Canada, at the Chateau Frontenac, on May 31, June 1 and 2, 1948.

The amendments to the Constitution, which were read at the meeting in 1947, were acted upon and passed. They were as follows:

> Article IV, Section 1. There shall be four classes of members—Active, Associate, Senior, and Honorary. Admission to membership in the Association shall be by election. There shall be no numerical limits on any class of membership. Only Active and Senior members shall have the privilege of voting or holding elective office.
>
> Article IV, Section 2. Election to all classes of membership shall be for life, subject only to the provisions of Section 3, which deals with resignation and/or expulsion for cause.

The Association voted to accept the proposals of the American Board of Surgery for the establishment of a subsidiary Board of Thoracic Surgery. The principles involved in the establishment of the Board of Thoracic Surgery, as reported by Dr. Carl Eggers, Chairman of the Committee which negotiated with the American Board of Surgery, were accepted by the Association.

The establishment of a Founders' Group will be at the discretion of the Board of Thoracic Surgery. Dr. William M. Tuttle, Detroit, Mich., is secretary of this Board. Complete membership of the Board and other details will be announced later.

The following recommendations of the Membership Committee were accepted by the Association:

Honorary membership was conferred upon Dr. Wolfgang Denk, Vienna, Austria.

The following active members were retired, at their own request, to Senior membership:

Dr. L. Wallace Frank, Louisville, Ky.
Dr. Gabriel Tucker, Philadelphia, Pa.

The following Associate members were elected to Active membership:

Dr. Herbert Willy Meyer, New York, N. Y.
Dr. Carl G. Merkel, Saranac Lake, N. Y.
Dr. Alexander E. W. Ada, New York, N. Y.
Dr. Robert G. Bloch, Chicago, Ill.
Dr. John R. Paine, Minneapolis, Minn.
Dr. Ross Robertson, Vancouver, B. C.
Dr. Daniel A. Mulvihill, New York, N. Y.
Dr. Rollin A. Daniel, Jr., Nashville, Tenn.
Dr. Earl B. Kay, Cleveland, Ohio
Dr. Edward M. Kent, Pittsburgh, Pa.
Dr. Laurence J. Miscall, New York, N. Y.
Dr. Lawrence M. Shefts, San Antonio, Texas
Dr. Edward J. McGrath, Cincinnati, Ohio

The following candidates were elected to Associate membership:

Dr. David Bancroft Aitchison, Mount Sanatorium, Hamilton, Ontario, Canada.
Dr. Oscar Auerbach, 121 Hamden Ave., Staten Island, N. Y.
Dr. Edward Benson Benedict, Massachusetts General Hospital, Boston, Mass.
Dr. George Valter Brindley, Jr., Scott and White Clinic, Temple, Texas
Dr. Robert K. Brown, 806 Metropolitan Building, Denver, Colo.
Dr. Ambrose Sevier Churchill, 1136 West Sixth St., Los Angeles 14, Calif.
Dr. Walter B. Crandell, Veterans Administration Hospital, White River Junction, Vt.
Dr. Forest Dewey Dodrill, 641 David Whitney Building, Detroit, Mich.
Dr. William H. Falor, 623 Second National Building, Akron 8, Ohio
Dr. Alfred Hurwitz, Veterans Administration Hospital, Newington 11, Conn.
Dr. Vincent Michael Iovine, 2500 Que Street, N.W., Washington, D. C.
Dr. Elgie K. Johnson, #1 Hanson Place, Brooklyn, N. Y.
Dr. Rutledge Starr Lampson, 179 Alleyn St., Hartford, Conn.
Dr. Roy George Klepser, 1150 Connecticut Ave., N.W., Washington, D. C.
Dr. James Monroe Mason, III, 1023 South 20th St., Birmingham 5, Ala.
Dr. Elmer Paul Robert Maurer, 827 Union Central Building, Cincinnati 2, Ohio
Dr. Neil MacDonald, Medical Arts Building, Windsor, Ontario, Canada
Dr. John R. McDonald, Mayo Clinic, Rochester, Minn.
Dr. James Francis O'Neill, 32 Roslyn Ave., Glenside, Pa.
Dr. Edward F. Parker, 70 Hasell St., Charleston, S. C.
Dr. John Lawrence Pool, 140 East 54th St., New York, N. Y.
Dr. Willis J. Potts, 707 Fullerton Ave., Chicago 14, Ill.
Dr. Lawrence Arthur Pratt, 10 Witherell St., Detroit 26, Mich.
Dr. Richard Allen Rasmussen, Blodgett Medical Building, Grand Rapids 6, Mich.
Dr. George Parrott Rosemond, 3401 N. Broad St., Philadelphia 40, Pa.
Dr. J. Gordon Scannell, Massachusetts General Hospital, Boston, Mass.
Dr. Paul W. Schafer, University of Kansas Medical Center, Kansas City, Kan.
Dr. Howard Errol Snyder, 103½ East Ninth Ave., Winfield, Kan.
Dr. William Carleton Whiteside, 342 Birks Building, Edmonton, Alberta, Canada
Dr. Julius Lane Wilson, Ochsner Clinic, 3503 Prytania St., New Orleans 15, La.

NOTICE

The twenty-ninth annual meeting of the American Association for Thoracic Surgery will be held on March 29, 30, and 31, 1949, in New Orleans, La. Headquarters will be at the Roosevelt Hotel.

Requests for hotel reservations should be mailed direct to Dr. Alton Ochsner, 1430 Tulane Avenue, New Orleans 13, La.

Abstracts for presentation of papers for the 1949 meeting must be received for consideration by the Program Committee, on or before Jan. 1, 1949. These abstracts should be submitted in *quadruplicate* and addressed to the Secretary of the Association, Dr. Brian Blades, George Washington University Hospital, 901 23rd St., N.W., Washington 7, D. C. They should not be sent to the Editor. The early date of the 1949 meeting makes it absolutely necessary that these abstracts be received before the deadline date. Abstracts received after Jan. 1, 1949, will not be considered.

Manuscripts for competition in the Rose Lampert Graff Prize should be sent directly to the Secretary of the Association not later than Jan. 1, 1949.

REPORT OF THE COMMITTEE ON BOARD OF THORACIC SURGERY

THE question of certification of thoracic surgeons was first discussed by the American Association for Thoracic Surgery in April, 1925, when it received an invitation to send representatives to a meeting of the National Board of Medical Examiners, to be held in Washington, D. C., May 6, 1925. Two delegates were appointed "to consider in a preliminary way the question of certification as to the qualifications to practice the several specialties in medicine and surgery." No definite action resulted from this meeting.

The question came up again in 1936, when the American Association for Thoracic Surgery appointed a special committee to make a study of the training of thoracic surgeons, as well as certification by a National Board. At the 1937 meeting of the Association the report of the Committee was accepted,* and the Association went on record with the following resolution:

> BE IT RESOLVED that the American Association for Thoracic Surgery recognize the American Board of Surgery as the parent organization which should properly be in control of all matters pertaining to the training and certification of surgeons and surgical specialists.
>
> BE IT FURTHER RESOLVED that the American Association for Thoracic Surgery signify to the American Board of Surgery its willingness to cooperate with it, if and when the special certification of thoracic surgeons seems advisable.

It was the hope of the Committee that such a relationship between the American Board of Surgery and a future Board of Thoracic Surgery might serve as a guide for the relations between the American Board of surgery and other surgical specialty boards.

As the result of the rapid growth and importance of thoracic surgery as a specialty during the succeeding years, fostered partly by the war and the attitude of the medical departments of the armed forces and the Veterans Bureau, there developed a demand for a specialty board in thoracic surgery.

The Association took cognizance of this desire of a large part of its membership and in 1945 the president re-appointed the original committee and instructed them to make a study. At the 1946 meeting, held in Detroit, the committee made its report. This resulted in the adoption of a resolution recommending the formation of a Board of Thoracic Surgery. The Association re-affirmed its previous attitude that the Board of Thoracic Surgery be subsidiary to the American Board of Surgery.

Thereupon the president appointed a small committee consisting of Carl Eggers, chairman; Alton Ochsner, and Jerome R. Head to confer with a similar committee appointed by the American Board of Surgery, as follows: Nathan Womack, chairman; Isaac A.

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*THE JOURNAL OF THORACIC SURGERY 7: 347, 1938.

Bigger, and Edward D. Churchill. All important questions dealing with the organization of a Board of Thoracic Surgery were discussed by these committees in joint session and incorporated in a report recommending the formation of such a board.

The necessary formalities with the Advisory Board for Medical Specialties were complied with. The Advisory Board approved the petition of the American Association for Thoracic Surgery and recommended that the American Board of Surgery take the necessary steps to arrange for the certification of thoracic surgeons.

The Committee of the American Board of Surgery informed the Committee of the American Association for Thoracic Surgery of their attitude and made some suggestions about organizing the board. This was made a part of the complete report of the Committee of the American Association for Thoracic Surgery.

At the meeting of the Association for Thoracic Surgery in St. Louis, May 29, 1947, the report was submitted and adopted unanimously, together with some resolutions implementing the report. The president was authorized to continue negotiations with the American Board of Surgery for the organization of a Board of Thoracic Surgery.

For this purpose the president appointed the present committee.

The committee has held two meetings. It has studied the numerous questions involved in the organization of a new board, its relationship to the American Board of Surgery, educational considerations, training requirements, and opportunities for training. It has tried to clarify various questions and on the basis of this study has drawn up the following report, which, if acceptable to the Association, may serve as a guide for the future Board of Thoracic Surgery.

The first question to answer was—What is meant by a surgical specialty board being subsidiary to the American Board of Surgery? Since the establishment of a board of Thoracic Surgery may influence the creation of other subsidiary boards there should be a clear understanding of the relationship of subsidiary boards in general, and of the Board of Thoracic Surgery in particular, to the American Board of Surgery.

In asking to become a subsidiary board of the American Board of Surgery, the Board of Thoracic Surgery undertakes to abide by the rules and regulations, and accepts the constitution and bylaws of the American Board of Surgery. No separate articles of incorporation and/or bylaws are therefore required.

The committee submits its opinion that surgical specialties as well as subspecialties should be developed on a broad education basis, and it therefore believes that candidates for examination in a surgical specialty, and in thoracic surgery in particular, must have had general surgical training and have been certified by the American Board of Surgery.

The committee recognizes the fact that the training of specialists, as advocated by most of the National Boards, is not the only way specialists may be developed. In many instances the requirements appear to be too rigid and have been drawn to favor men with a definite program early in their career. It is recognized that there are many men entering a surgical residency who do not know at the time whether they have special liking or aptitude for a surgical subspecialty. Opportunity may play an important role.

Relatively few of the present leading members of national surgical societies have followed a prescribed rigid course of training. There are many different factors entering into the development of a specialist. It is frequently not until after a surgeon has been practicing for awhile, that he becomes interested in a special subject, or acquires special skill and perhaps has opportunity to develop along special lines. With our present system such a surgeon is excluded from certification by a specialty board.

The important points to remember are that a surgical residency is basic surgical training, which is required of every surgeon who desires certification. Preparation for the practice of a surgical subspecialty, on the other hand, is supplementary to this basic training.

During his residency the candidate should be taught surgical principles; he should rotate through the different surgical specialty departments; he should learn surgical technique and later be allowed to operate independently. In addition he should study the pathologic material of his own cases as well as the basic sciences relating to his subject.*

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*See article on Basic Science Instructions in Hospital Residencies, J. A. M. A. 133: 687, 717, 1947.

institutions training programs were contemplated in the near future. Critical evaluation of these available data indicated adequate residency training in thoracic surgery in at least thirty-five hospitals. Some of these hospitals can accommodate several residents.

A current questionnaire suggests a substantial increase in the number of available satisfactory residencies in thoracic surgery.

It appears that in the future there will be sufficient opportunity for training to allow qualification for the Board of Thoracic Surgery.

7. *Founders Group.*—To be composed of surgeons who have made meritorious contributions to thoracic surgery, as follows:

> (a) Active and senior members of the American Association for Thoracic Surgery, who have been certified by the American Board of Surgery, will automatically be founder members.
> (b) Other surgical members of the American Association for Thoracic Surgery will have their records reviewed by the Board, and may be recommended for founder membership with or without application.
> (c) Other surgeons, certified by the American Board of Surgery, who upon application, and after review of their qualifications, are found to meet the requirements of the Thoracic Board.

The Founders Group will be kept open for two years after organization of the Board.

8. *Group to be Certified by Examination.*—Only candidates who have been certified by the American Board of Surgery are eligible for examination.

The Board of Thoracic Surgery will review the candidate's training or accomplishments in thoracic surgery. If acceptable, he will be notified to appear for examination.

9. *Examinations.*—The Board of Thoracic Surgery will be governed by the rules laid down by the American Board of Surgery pertaining to examinations as well as re-examinations.

Rules may be changed, however, at the discretion of the Board of Thoracic Surgery.

10. *Fees.*—It is suggested that the fees for candidates to be certified in thoracic surgery be as follows:

> Founders Group: For those who will be admitted to this group, a certificate will be issued. The fee will be $25.
> Group to be Certified by Examination: For the special examination in thoracic surgery and the issuing of a certificate, the fee will be $50. The examination is to be completed in one day. The fee for re-examination will be $25.

11. *Certificates.—Certificates to the Founders Group* are to be issued according to the suggestions mentioned previously, as follows:

> (a) To active and senior members of the American Association for Thoracic Surgery, who have been certified by the American Board of Surgery, without examination.
> (b) To those surgical members of the American Association for Thoracic Surgery, who are found to be eligible. Application may or may not be required.
> (c) To other surgeons certified by the American Board of Surgery, upon application and recommendation of the Board of Thoracic Surgery.

Certificates to those admitted by examination are to be issued after the candidates meet the requirements and successfully pass the examinations.

Respectfully submitted by
Carl Eggers, chairman
Brian Blades
Ethan Flagg Butler
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Original Communications

PRIMARY PULMONARY MALIGNANCY

Factors Influencing Survival

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IN THE fifteen years which have elapsed since Evarts Graham performed the first successful pneumonectomy for carcinoma of the lung on a human subject, the concepts formerly held concerning this disease have been radically modified. It is now recognized that instead of being rare, it is a common type of malignancy, being preceded in frequency only by carcinoma of the gastrointestinal tract, skin, and prostate. It is now recognized that instead of being incurable, it is susceptible to cure in a significant proportion of cases, if the patient is seen while the growth is still confined to the lung. Finally, it is now recognized that resection of the malignant growth, in addition to being the only treatment from which cure can be expected, is also a perfectly practical method of therapy. A number of variations in technique have been devised, but resection has been established as the appropriate and logical form of therapy for carcinoma of the lung, and basic technical principles for its performance have been standardized. Present problems in management are concerned not so much with the type of treatment as with how to extend the benefits of surgery to more patients and thus to increase the possible salvage.

The present communication consists of an analysis of various factors which appear to influence end-results and survival of the 548 patients with primary pulmonary malignancy observed at Charity Hospital of Louisiana at New Orleans (on the Tulane University School of Medicine Service) and in private

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practice at the Ochsner Clinic from 1934, when exploration was performed on the first patient for this disease at Charity Hospital, to May 1, 1948. The same general features, apparent in previous reports,[2-6] were noted in this cumulative series, and they need be mentioned only briefly here. The incidence of primary pulmonary malignancy continues to increase, perhaps because the disease is actually more frequent, but in large part because more cases are being recognized. It occurs predominantly in men in the fifth, sixth, and seventh decades of life. No etiologic factor has been found to have special significance. With few exceptions the growths are bronchiogenic in origin. In the early stages of the disease the clinical picture is not characteristic and the usual symptoms are seldom all present in any given case. The physical findings are also not characteristic. In fact, the lack of a characteristic clinical picture, particularly in the early stages, and the general failure to appreciate the frequency of the

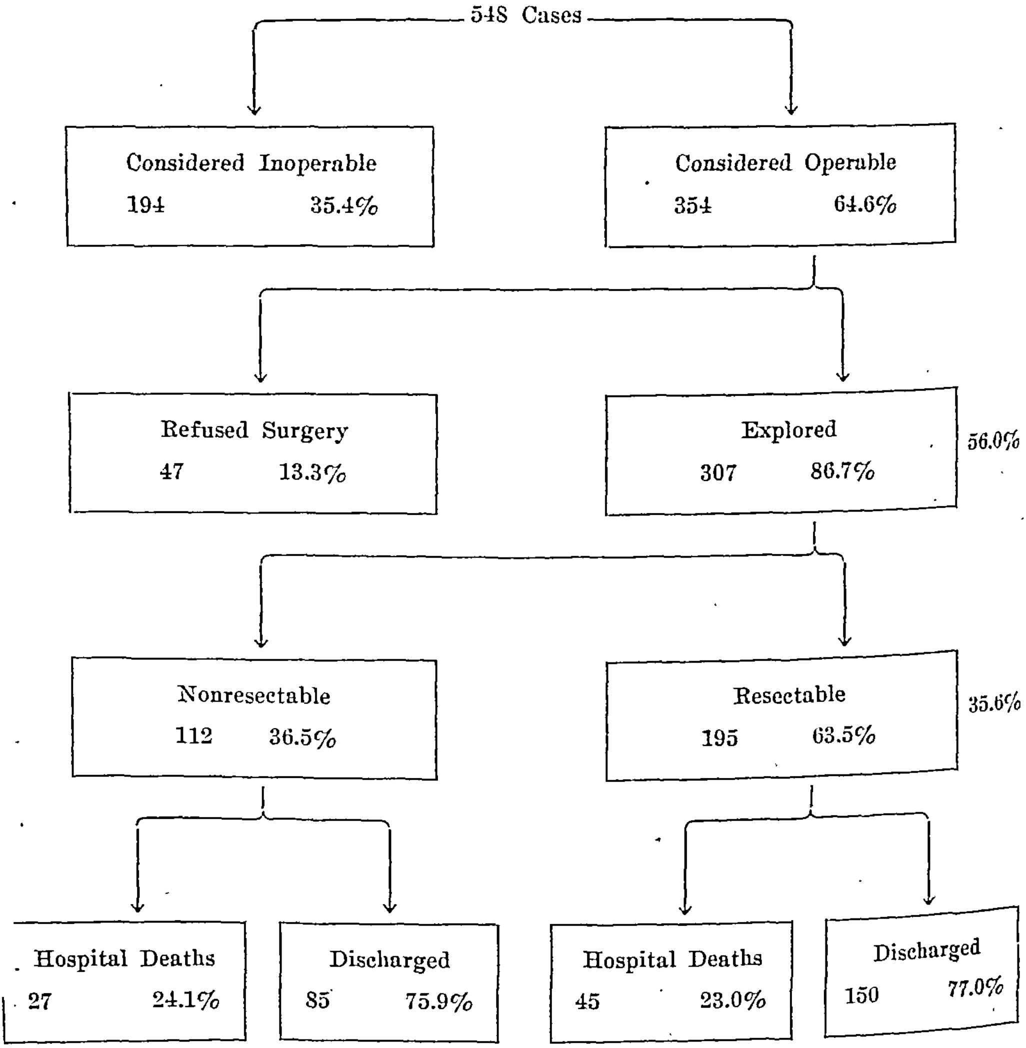

Chart 1.—Schematic representation of results in 548 cases of primary pulmonary malignancy.

disease are perhaps the two most important causes for the present low rate of cure.

It is evident that improvement is badly needed from the fact that among these 548 cases (Chart 1), the disease was far too advanced in 194 patients (35.4 per cent) to warrant even exploratory operation. Forty-seven patients considered suitable for exploration refused surgical treatment. Of the 307 patients in whom exploration was done, only 195 (63.5 per cent of the explorations and 35.6 per cent of the total series) had resectable growths. In other words, of every three patients in whom the diagnosis of carcinoma of the lung could be established on reasonable clinical grounds, one was eliminated as a candidate for operation because the growth was obviously inoperable, one had a nonresectable tumor proved at operation (or refused operation), and one had an actually resectable tumor.

These figures, however, as indicated in a previous review,[4] compare favorably with most series on record. The proportion of operability, in particular, is higher than is usually reported. This is still, however, an unsatisfactory showing, and we all share the responsibility of improving it.

DIAGNOSIS, OPERABILITY, AND RESECTABILITY

Diagnosis.—The most obvious and important method of improving the percentage of resectable cases of carcinoma of the lung—the only means now apparent by which the end results can be greatly improved—is by earlier diagnosis. It has often been stressed that the most essential factor in early diagnosis is constant awareness that the disease may be present. Primary pulmonary malignancy should be suspected as a possible diagnosis in every man over 40 years of age who has unexplained thoracic discomfort, a persistent cough, hemoptysis, or any other symptom or sign referable to the respiratory system. Nor should carcinoma of the lung be eliminated as a possibility until every diagnostic method has been exhausted, including roentgenography, bronchography, bronchoscopy, and cytologic examination of the sputum or bronchial secretions.

Roentgenography should be the initial step in the diagnostic routine in every suspected case. In seven patients without pulmonary symptoms in whom no pulmonary neoplasm was suspected, carcinoma of the lung was discovered on routine roentgenography of the chest and proved to be resectable. Such an experience clearly indicates the great value of roentgenography as part of the routine medical examination of all men in middle life and beyond.

Of all diagnostic methods bronchoscopy with biopsy is the most accurate, though unfortunately it is not applicable in all cases because of the peripheral location of some of the tumors. Of the 195 cases of resection in this series, bronchoscopy was done in 161 (82.6 per cent) and not done in the remaining cases because the lesion was located so far out in the bronchial tree that it obviously could not be visualized (Chart 2). Positive evidence of malignancy by bronchoscopic biopsy was obtained in only 37.9 per cent of the 195 cases of resection. Thus, of the entire series of resectable lesions, bronchoscopy provided a positive diagnosis in only a little more than one-third of the cases. This is readily explained by the location of the tumors as shown by a careful pathologic examination of the resected specimens. Whereas there was some variation according to the histologic character of the growth, the lesion was situated peripheral to the lobe bronchi in approximately one-half the cases (Fig. 12). The chance of bronchoscopic visualization of the more centrally located tumors is further reduced by the fact that a large proportion of them originated in the upper lobe bronchi beyond the range of easy bronchoscopic visualization. It is obvious from these considerations that bronchoscopy has definite limitations as a diagnostic procedure and that a large proportion of patients with carcinoma of the lung would be denied proper treatment if operation were limited to those with positive results of biopsy.

Cytologic examination of the sputum or of the bronchial secretions is another important method and one which may prove, as experience with it increases, to be the most practical and most useful of all.

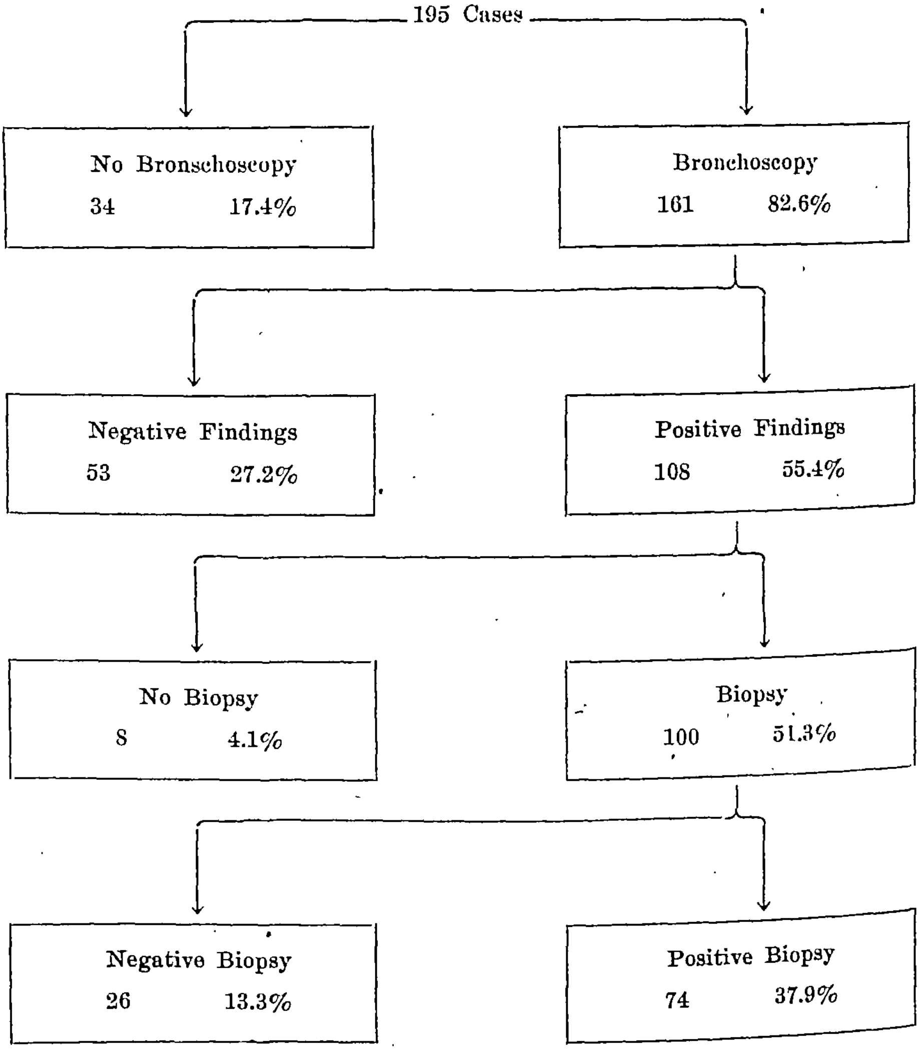

Chart 2.—Schematic representation of results of bronchoscopy in 195 cases of resection for primary pulmonary malignancy.

If a probable malignancy of the lung cannot be positively identified or excluded by any of these methods, then the surgeon is fully justified in recommending exploration of the chest. Exploratory thoracotomy is a procedure which now carries a minimum risk and if it is not applied in properly selected cases, many patients with carcinoma of the lung will be denied the opportunity for cure. A positive diagnosis was established prior to surgical exploration in 117 (60 per cent) of our 195 cases of resection and in 208 (67.8 per cent) of the entire series of 307 cases in which exploration was done.

Extension of Criteria of Operability.—Another method of increasing the proportion of resectable cases of primary pulmonary malignancy is by broadening the criteria of operability or, more accurately, by restricting the contraindications. There are few reasons, other than absolute inoperability, for not carrying out exploration on the chest of a patient with suspected carcinoma of the lung. Involvement of the phrenic or recurrent laryngeal nerves is not a definite contraindication. Such involvement was present in several patients in this series in whom resection proved possible. The definite presence of distant metastases, obvious involvement of the trachea or carina, and the presence of malignant cells in the pleural fluid indicate that the growth has passed beyond the stage of operability. In the absence of these findings it is our practice to consider operation, since exploration frequently reveals that a lesion which clinically appears to be inoperable is actually resectable.

The proportion of resectable cases in this series was further increased by the use, in addition to pneumonectomy, of certain supplemental procedures in cases in which the growth had extended beyond the substance of the lung. These procedures included resection of a portion of the pericardium with intrapericardial ligation of the hilar vessels (19 cases), suture of the auricle (10 cases), and resection of part of the diaphragm (9 cases), or thoracic wall (11 cases). Supplemental procedures were necessary only when the neoplasm had extended beyond the borders of the lung. Hence, these resections were all considered palliative and some surgeons might even question the wisdom of operation on such extensive growths. We do not share this doubt. We perform the palliative operation whenever the risk entailed is not excessive for two reasons: (1) the patient's remaining span of life is more comfortable when involved, necrotic, and infected pulmonary tissue is removed, because he is spared the sepsis and continued exudation which he would otherwise be obliged to endure. The procedure, therefore, seems warranted from the humanitarian standpoint alone. (2) There is some evidence, as will be pointed out later, that palliative resection favorably influences the period of survival. In fact, some of these patients have survived five years with no evidence of recurrence.

ANALYSIS OF RESULTS

Mortality and Causes of Death

There were 45 hospital deaths (23 per cent) in the 195 patients in whom resection was possible (Fig. 1). An analysis of the hospital death rate from the standpoint of chronology reveals a steady improvement with the passage

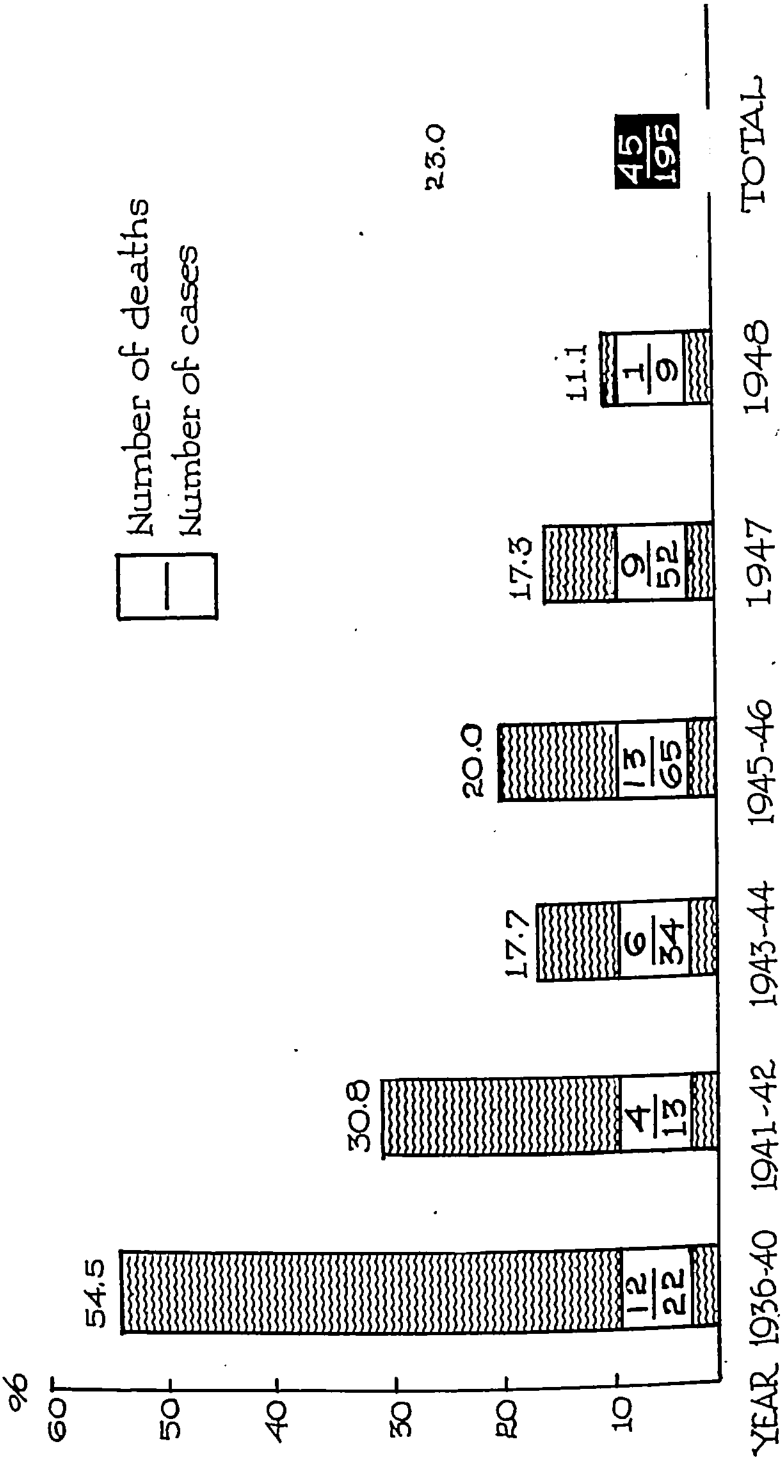

Fig. 1.—Hospital mortality in 195 cases of primary pulmonary malignancy treated by resection.

of time. The mortality for the 1947-1948 series (10 of 61 cases, 16.4 per cent) is less than one-third of the mortality rate for the first five-year period of the analysis (12 of 22 cases, 54.5 per cent). It may reasonably be assumed that the progressive reduction is a reflection of improvements in surgical technique, in anesthesia, and in preoperative and postoperative care.

The present mortality of 16.4 per cent for the 1947-1948 series is relatively high, it is true, but an analysis of the causes of death in this series (Fig. 2) leaves considerable doubt that it can be materially reduced. Such causes as hemorrhage, pneumothorax, and anesthetic complications are chiefly due to technical errors and are therefore preventable, but they accounted for only a small part of the mortality in recent cases. Possibly some deaths from postoperative empyema can be prevented, but the use of sulfonamides and penicillin does not seem to be the answer to the problem.[4, 5]

To a certain extent the major cause of death after pneumonectomy may be considered beyond the surgeon's control. In this series, as in most reported series, almost one-half of all deaths following operation were due to cardiovascular disturbances, which are frequently present, together with other constitutional diseases, in many patients in the age group in which pulmonary malignancy is most frequent. They represent an unavoidable element of risk which must be assumed in pneumonectomy for this condition unless the criteria of operability are so strictly limited that patients with cardiovascular disease are excluded from surgical treatment and are thus denied their only chance of life. In other words, the postoperative mortality of carcinoma of the lung might thus be reduced, but the final mortality of the disease would undoubtedly be increased. Perhaps with greater care in the preparation of these patients for operation the risk of cardiovascular deaths can be reduced and for this reason a cardiologist has been added to our thoracic team.

In the total series of 195 cases of resection the procedure was considered palliative in 138 (70.8 per cent) and curative in 57 (29.2 per cent), the former being determined by extension of the lesion beyond the borders of the lung either grossly or by histologic demonstration of regional lymph node metastasis and the latter by the absence of these criteria.* The fact that in 7 out of 10 cases in which resection was possible the lesion was recognized as being beyond the likelihood of surgical cure further emphasizes the need for earlier diagnosis.

The operative risk is potentially greater in palliative than in curative resections as is shown by the operative mortality in our series, the corresponding figures being 25.3 per cent and 17.5 per cent (Fig. 3). It is interesting to observe, however, that since 1942, with improved management of poor risk patients, the risk of operation in the palliative cases, which was formerly high, has been reduced until it is now about the same as that in the curative cases (Fig. 3).

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*In a few cases classified as curative resections in our previous publication,[4] histologic studies of the original material revealed lymph node metastasis. These cases have now been transferred to the palliative group. For this reason some differences may be observed between the results here presented and those previously published.

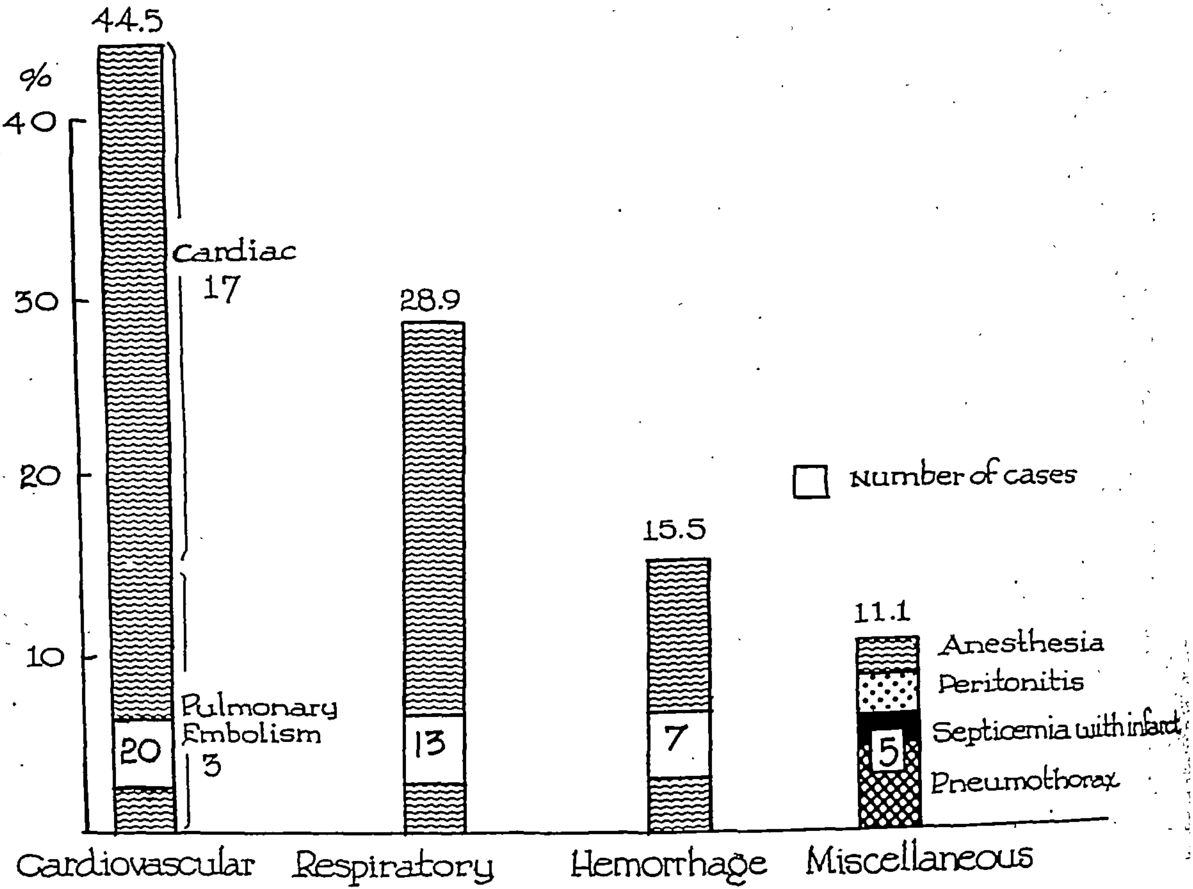

Fig. 2.—Causes of death in the 45 patients dying in the hospital among the 195 patients with primary pulmonary malignancy treated by resection.

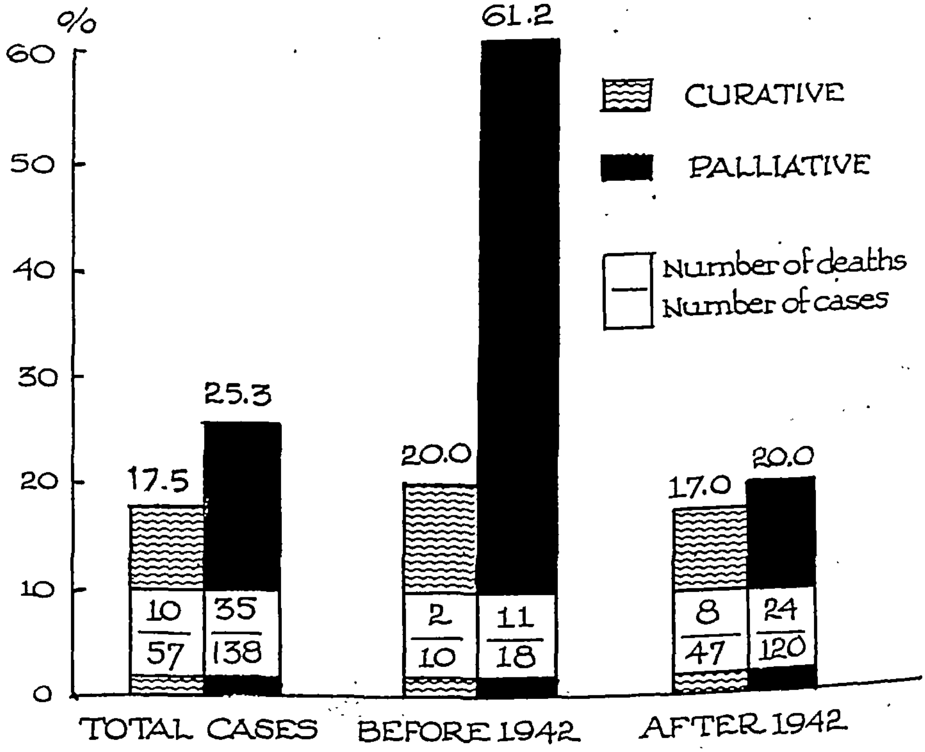

Fig. 3.—Hospital mortality in palliative and curative cases of resection.

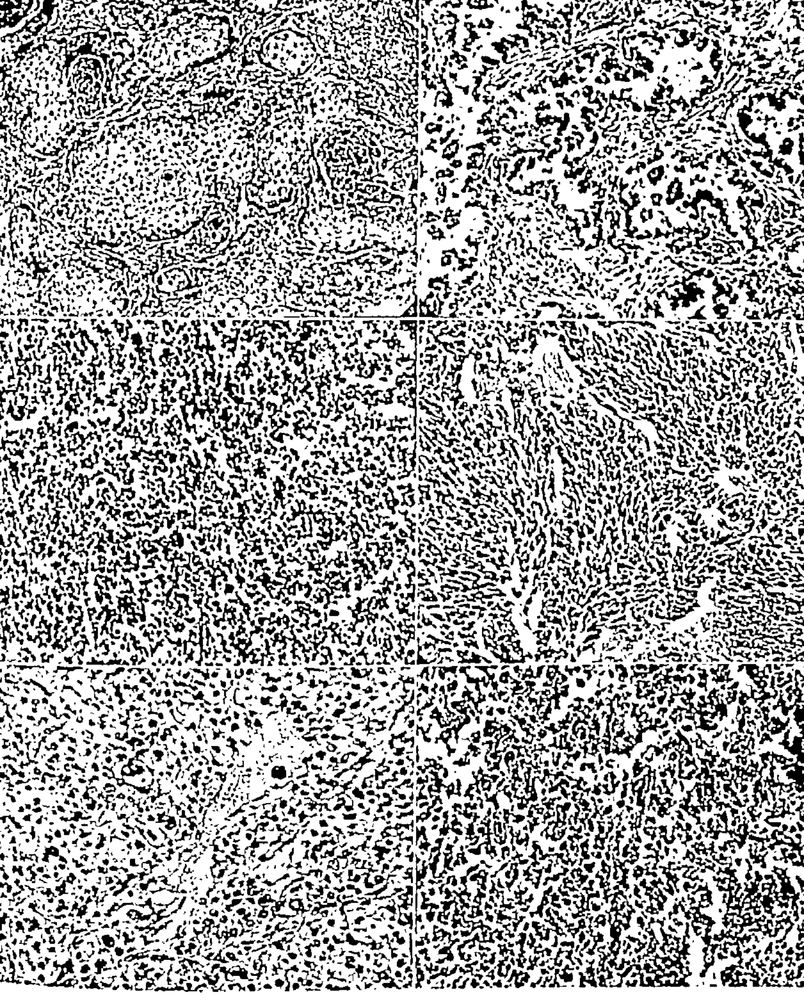

Fig. 4.—Histologic types of carcinoma of the lung. *A*, Epidermoid (squamous cell) carcinoma grade II; a few small epithelial pearls are present. *B*, Adenocarcinoma; low columnar and cuboidal tumor cells are forming irregular glandlike spaces in the fibrous stroma; small papillary projections of the tumor extend into the lumens of these spaces. *C*, Undifferentiated carcinoma, small round-cell type; the tumor is made up of fairly uniform small, round, dark-staining cells without any distinctive arrangement. This tumor can be confused with lymphosarcoma unless careful attention is paid to the structure of the nuclei and to the occasional regions in which the tumor cells are arranged along the borders of the delicately branching fibrous stroma. *D*, Undifferentiated carcinoma, oat-cell type; this tumor is not always classed among the undifferentiated carcinomas since the characteristic fusiform shape of the cells give it a distinctive appearance. In the past such tumors have sometimes been classified as sarcomas, but study of numerous sections will usually reveal some transitions to definite epithelial structures. *E*, Undifferentiated carcinoma, large clear-cell type; this tumor may be confused with reticulum-cell sarcoma but careful study will usually show a few attempts to form glandlike structures or some small nests of keratinized cells. *F*, Undifferentiated carcinoma, unclassified; this slide shows a tumor from the heterogenous group of undifferentiated tumors which were not subclassified and which appear in the figures as "undifferentiated carcinoma, other." The tumor cells are pleomorphic and bizarre giant forms are present. The picture is complicated by the presence of inflammatory cells resulting from secondary infection.

Histologic Studies.—In order to evaluate the factors which affect survival it is important to have as complete data as possible on all aspects of each case. For this reason, the subsequent analysis has been limited to the 195 cases in which resection was done. Every patient in this series has been traced to May 1, 1948. The hospital record of each patient was reviewed, the clinical signs and symptoms were tabulated, and the precise location of the neoplasm was determined as exactly as possible from the original gross pathologic descriptions and bronchoscopic reports.

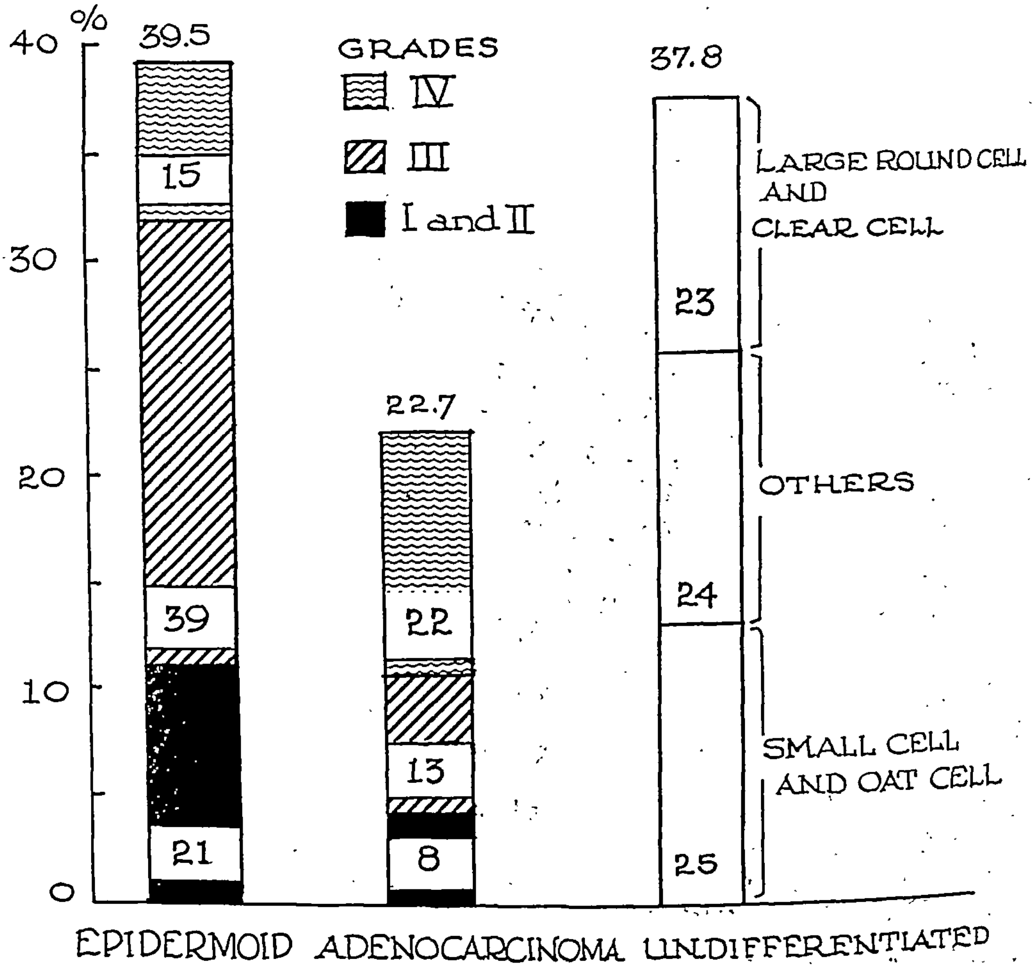

Fig. 5.—Graphic representation of distribution by histologic type and grade of the 190 cases of resection for carcinoma of the lung.

The original slides were obtained in all but one of these cases and in order to assure an objective analysis the slides were independently rediagnosed, classified, and graded by one of us (C. E. D.) without any knowledge of the original diagnosis or the clinical history or fate of the patient. Many classifications of carcinoma of the lung have been proposed, but for the purposes of this study only three major groupings were used: epidermoid (squamous cell) carcinoma, adenocarcinoma, and undifferentiated carcinoma. The cases of epidermoid and adenocarcinoma were each further divided into four grades of histologic malignancy and the cases of undifferentiated carcinoma were arbitrarily divided into three subgroups, according to cell type: first, the small round-cell and the oat-cell carcinomas; second, the large round-cell and clear-cell tumors; and third, a miscellaneous group of irregular cell types designated as "other" (*Figs. 4 and 5*). *All carcinomas were assigned to one of these groups* and subgroups at the time the slides were reviewed without knowledge of the fate of any of the individual patients and no subsequent changes were made in this classification. Carcinoma was found in the sections from 190 of the 195 *resected lungs. The lesions in the remaining 5 patients were:* one low-grade neurofibrosarcoma, one Hodgkin's disease, one lymphosarcoma, one malignant melanoma, and one carcinoma diagnosed at the time of operation, but excluded from this study since the original slides were not available. Two cases originally diagnosed as fibrosarcoma and so reported in previous publications[4, 5] were reclassified as undifferentiated carcinomas and one of the cases previously reported as lymphoblastoma was reclassified as Hodgkin's disease. It is worth mentioning that each patient in whom the diagnosis is now neurofibrosarcoma, lymphosarcoma, and Hodgkin's disease is still living 12 years, 6 years, 9 months, and 3 years, 8 months, respectively, after pneumonectomy. The patient with the malignant melanoma died 2 weeks postoperatively. The patient in whom the original diagnosis was carcinoma but who was excluded from this study because the original slides are no longer available is still living 8 years, 3 months after operation.

Since the various factors affecting survival are generally evaluated in terms of the number of patients alive at yearly intervals after treatment, correlations of this character were made whenever possible. In other instances a "*fatality rate*" was determined by adding up *the total number of years of* observation on all patients living and dead in a particular group and dividing the total number of deaths by this figure to give a fatality rate in terms of the number of deaths per patient-year of observation. This is an accepted method of statistical treatment and has the advantages of taking into account the length of survival of those patients who died and at the same time including living patients of both long and short survival.

Survival Rates

Every patient in this series who survived operation and who was submitted to surgical treatment six months ago or longer has been followed up to date. Because the patients involved in these calculations were operated upon at varying times in the past, the number of cases in each category is different, and the numbers become progressively smaller as the possible survival time increases. Thus, patients operated upon only one year ago have had no opportunity to survive longer than one year. Accordingly, the survival rate in this analysis is calculated on the basis of the possible period of survival following operation. In some instances, as will be appropriately indicated, the survival rate analyses are made for the entire series of 195 cases of resection of primary pulmonary malignancy, whereas in others it is based only upon the 190 cases of resection of carcinoma of the lung.

Of the 181 patients with primary pulmonary malignancy operated upon six months ago or longer, 99, a little more than one-half, were alive at the end of this period; the 62 deaths include the fatalities which occurred in the hospital immediately after operation (Fig. 6). At the end of one year not quite 40 per cent of the patients submitted to resection were still alive. At the end of the second, third, fourth, and fifth years the proportion of survivals was about the same for each year, ranging from 20 to 27.5 per cent. To express it differently, the survival curve drops rather rapidly within the first year after pneumonectomy for primary pulmonary malignancy, but by the second year it begins to be stabilized, and it continues almost as a plateau from the third to the fifth year. The assumption, therefore, seems warranted that a patient who lives through the second year after operation has a good chance of being alive at the end of five years.

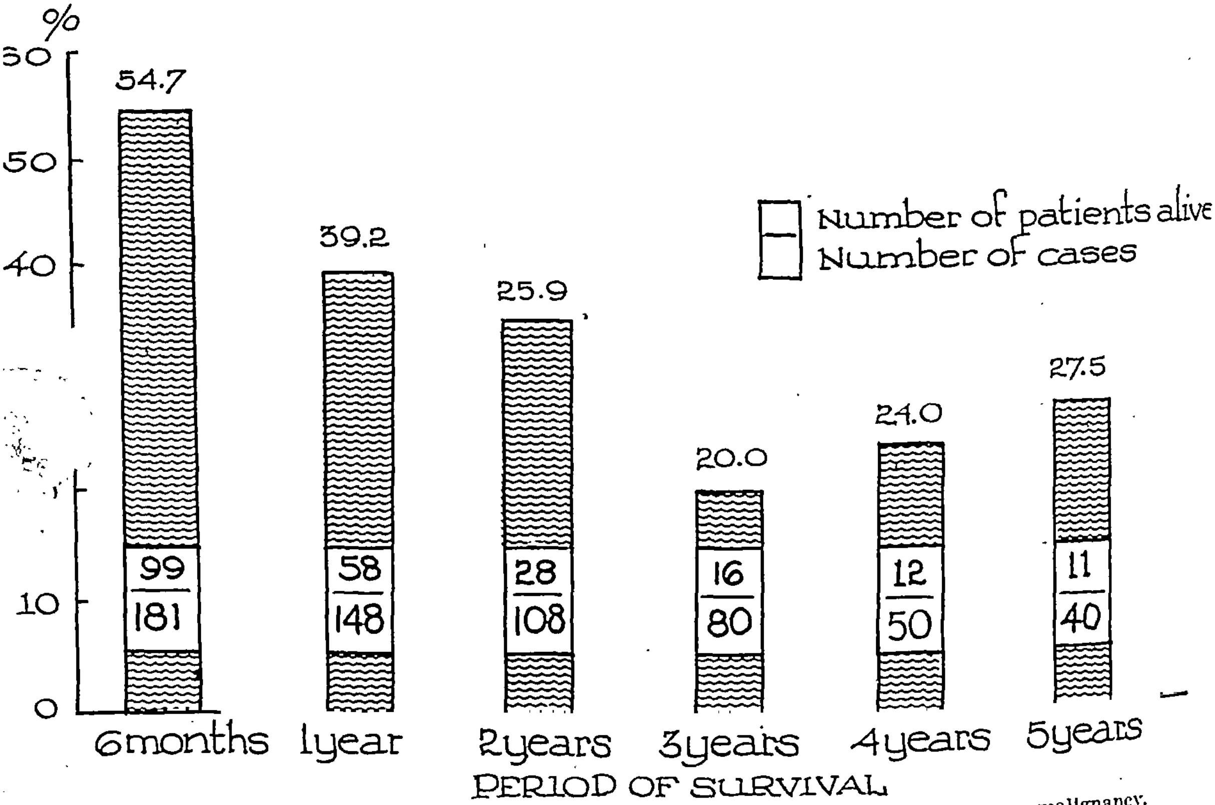

Fig. 6.—Gross survival rate after resection in 195 cases of primary pulmonary malignancy.

With the progressive improvement, through increasing experience, which has taken place in operability and in hospital mortality in this series, it was thought possible that a similar improvement might be reflected in the survival rates for the later periods of this experience. Accordingly, the patients were divided into two groups, depending upon whether the operation was carried out before or after 1942, and their survival rates were compared. No significant difference in the rates was evident, which seems to indicate that though improvements in technical management have resulted in a reduction of the hospital mortality, they have had little if any influence on the length of survival.

Of all factors influencing the survival rate in carcinoma of the lung the most obvious is the extent of the growth, that is, whether or not it has extended beyond the borders of the lung at the time of operation. As previously stated, resections of lesions which had extended beyond the borders of the lung were considered palliative rather than curative. When the cases in this series are compared from this standpoint, the difference in survival time is, as might be expected, significantly in favor of patients who had no extrapulmonary extension of the growth at the time of operation (Fig. 7).

The question may fairly be raised as to whether patients with extension of the growth beyond the lung might not have survived just as long without operation. To determine this point, the cases in which resection was not done were divided into two categories, those in which there was no surgical treatment at all because the patient refused operation or the growths were inoperable and those in which exploration showed the growth to be inoperable, and the survival times were compared. It is realized that these cases are not strictly comparable to the cases of resection since the former are more advanced than the latter. However, the cases without resection include 47 patients in whom the lesion was considered operable but who refused operation, in two-thirds of whom the lesion probably would have been resectable. The patients in whom resection was not done showed practically the same rate of survival whether or not exploration had been carried out (Fig. 8). At the end of six months, only about 15 per cent were still alive, and at the end of three years none were alive. A comparison of the results in these cases with the results in the cases of resection shows that whereas in the former group none lived three years, among the latter 20 per cent survived this period (Fig. 9). It is also significant that 10 per cent of patients with palliative resections survived more than three years, whereas none with lesions considered inoperable lived so long. This lends support to our conviction that palliative resections are justified both for symptomatic relief and prolongation of life. A graphic comparison of the results in cases of nonresection, in all cases of resection, and in cases of resection categorized as to whether the growth was localized or had extended beyond the pulmonary tissue makes clear these differences in the survival rates (Fig. 10).

At the present time the gross survival rate in carcinoma of the lung at the end of five years is 7.7 per cent. This is not high, but it is as high or higher than the present survival rate in carcinoma of the stomach which, according to the representative literature and our own experience, does not exceed 6 to 8 per cent at the most and in some series is as low as 2 per cent. The percentage of operability in carcinoma of the stomach, furthermore, is 57 per cent, whereas that of carcinoma of the lung is 67 per cent, and the percentage of resectability in carcinoma of the stomach is 25 per cent, against 35.2 per cent for carcinoma of the lung. It, therefore, appears that the operability and rate of cure in

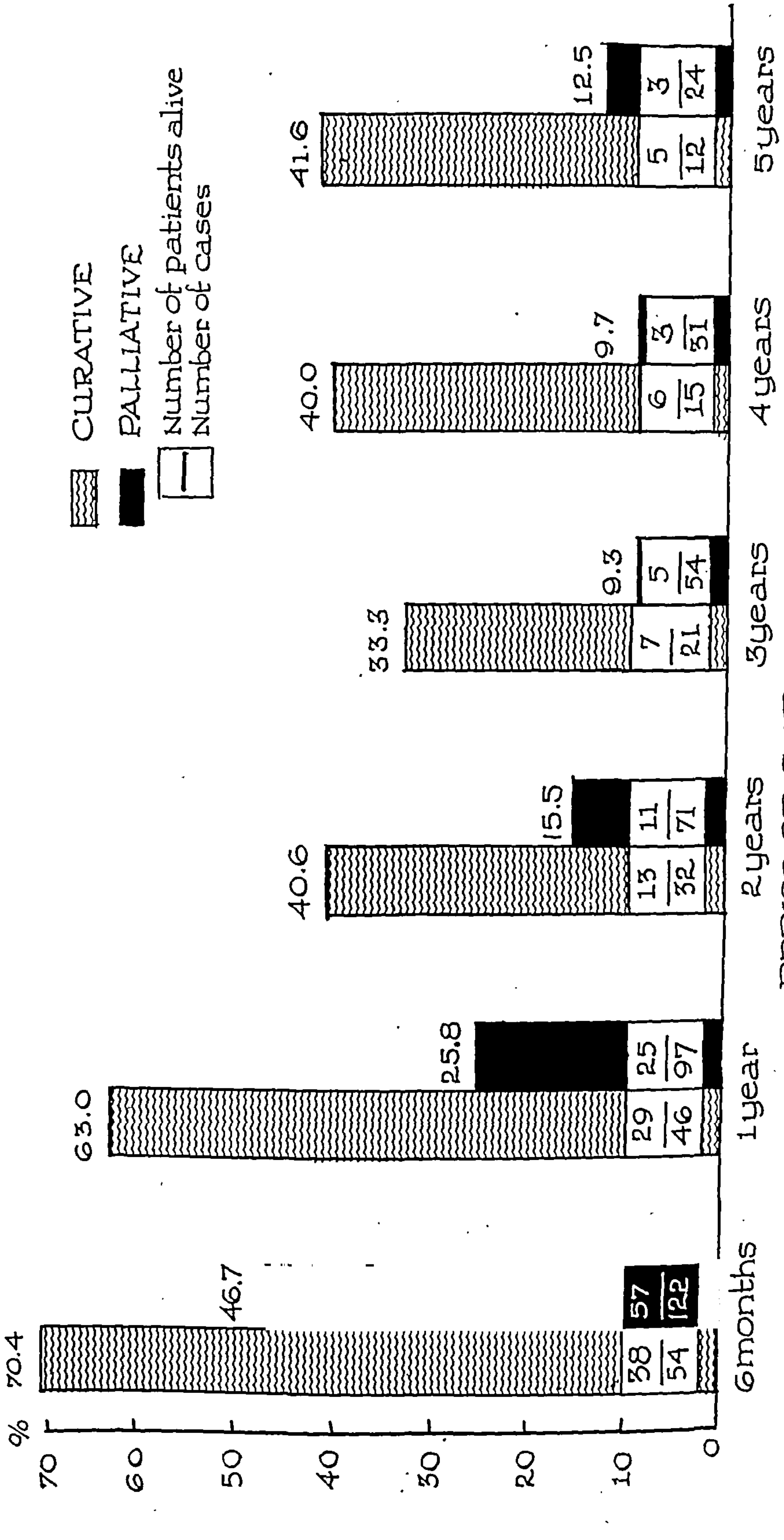

Fig. 7.—Graphic representation of survival rates after palliative and curative resection in the 190 cases of carcinoma of the lung.

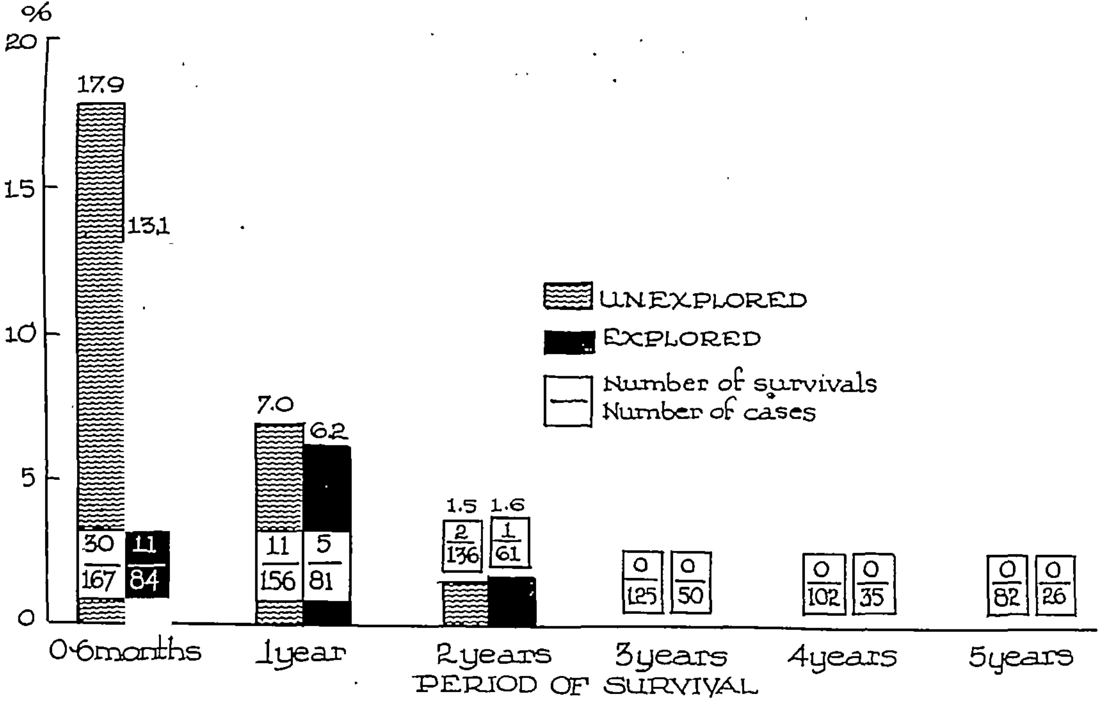

Fig. 8.—Gross survival rate in cases of nonresection for carcinoma of the lung.

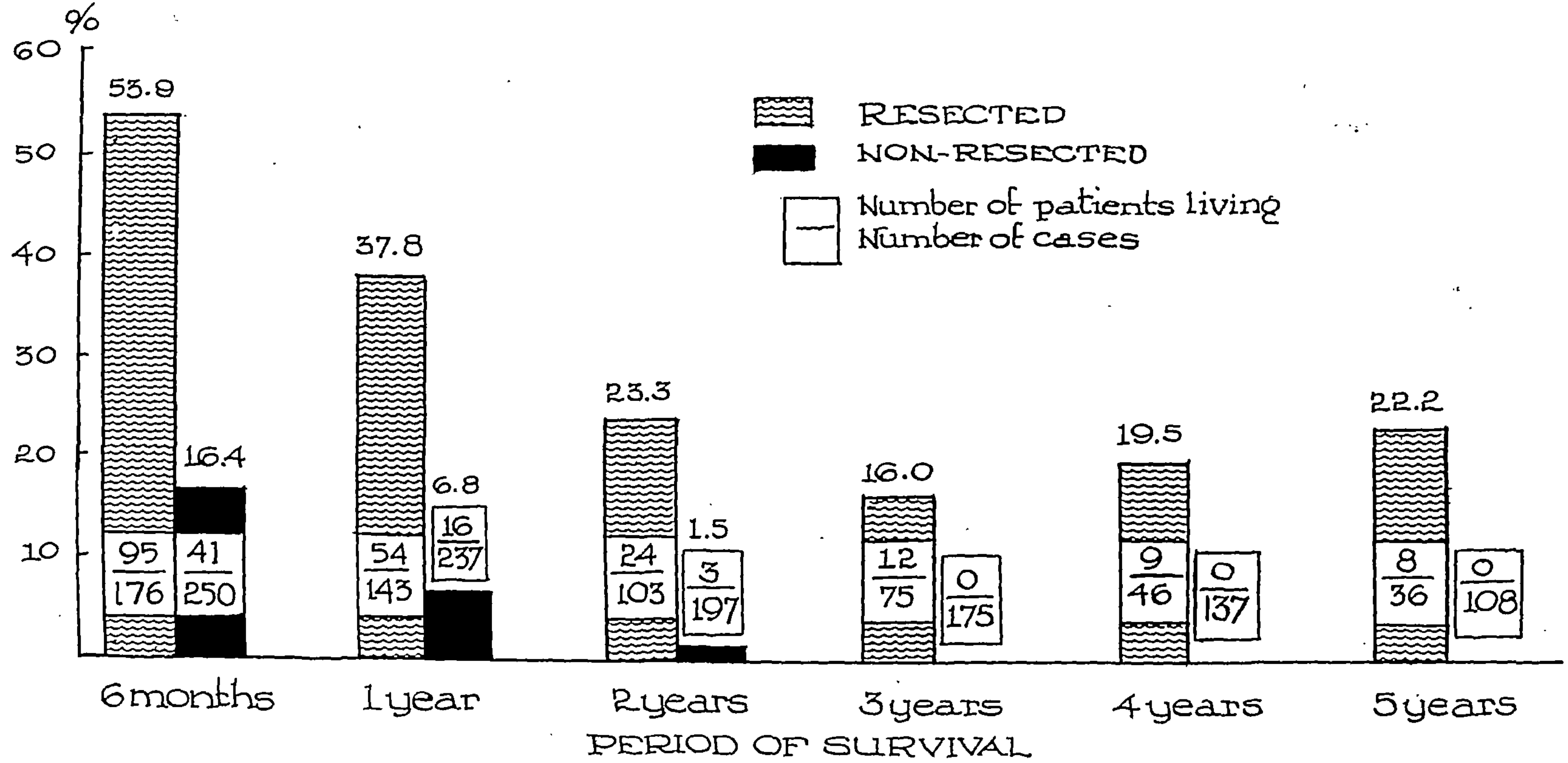

Fig. 9.—Comparison of survival rates among cases of resection and nonresection for carcinoma of the lung. The difference between the figures shown here for the cases of resection and those shown in Fig. 6 is explained by the fact that there is included in the latter the four cases diagnosed such as neurofibrosarcoma, Hodgkin's disease, lymphosarcoma, malignant melanoma, and the one case of carcinoma in which the original slides are no longer available.

carcinoma of the lung are as good as, or better than, in carcinoma of the stomach in spite of the far greater general awareness of the latter. It is probable that the results in carcinoma of the lung will be greatly improved as the problem becomes more widely recognized.

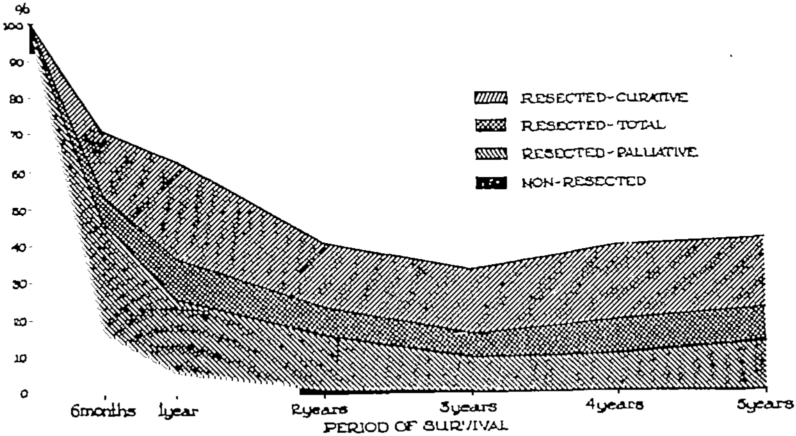

Fig. 10.—Graphic representation of survival rates in cases of resection and nonresection for carcinoma of the lung.

Special Factors Affecting Survival

Location and Extent of Tumor.—Because of the clinical impression indicated previously,[2] that greater hazards were associated with right than with left-sided lesions, an analysis was made of the fatality rate according to lobe involvement (Fig. 11). This analysis confirmed the clinical impression that right-sided lesions carried a higher fatality than left-sided lesions, the corresponding figures being 93 and 65 per cent. Among the curative cases the fatality rate was about the same for all lobes, but among the palliative cases lesions in the right upper lobe carried a much more grave prognosis than in the left upper lobe. The fatality rates for lesions arising in the main stem bronchi, lobe bronchi, and peripheral portions of the lung were about the same, the figures being, respectively, 79, 71, and 68 per cent. In the entire group central and peripheral lesions were about equally divided. The epidermoid carcinomas were predominantly central and the adenocarcinomas were predominantly peripheral (Fig. 12).

Age.—Since age is generally recognized as an important consideration in determining both the risk of operation and the survival period after operation, an analysis of this factor was made in several ways. A comparison of the age distribution by histologic types showed that a higher proportion of the epidermoid and undifferentiated forms of bronchiogenic carcinoma occur in the older age groups than do the cases of adenocarcinoma (Fig. 13). This is more strikingly demonstrated by determining the relative incidence of each of these histologic types of carcinoma in different age periods. From this analysis it would seem that before the age of 50 years the chances of having any one of these types are about equal, but after the age of 60 years there is a two and one-half times greater chance of having an epidermoid carcinoma than an adenocarcinoma, whereas the proportion of undifferentiated neoplasms shows little change (Fig. 14).

The influence of age upon survival was determined by computing the fatality rates according to the age of the patient at the time of operation. As might be expected, the fatality rises with increasing age (Fig. 15). Since it is conceivable that this may be due in great measure to the greater operative hazard in elderly patients, a similar analysis was made excluding all deaths

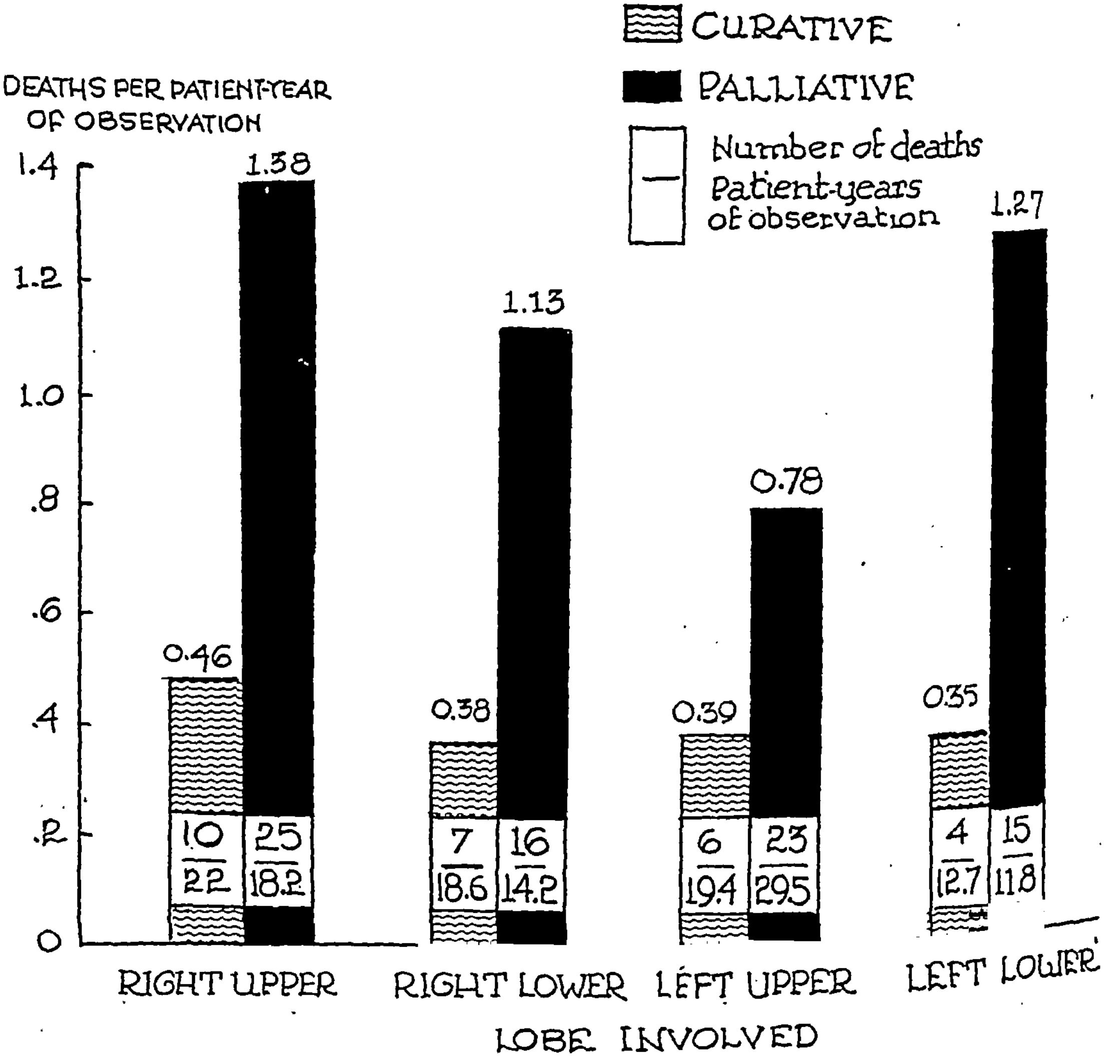

Fig. 11.—Fatality rate according to lobe involved in the 190 cases of resection for carcinoma of the lung.

occurring within thirty days after the operation. This showed that the pronounced increase in fatality after the age of 60 was due principally to early postoperative deaths (Fig. 15). This would tend to support the clinical impression that the hazards of operation become much greater with increasing age.

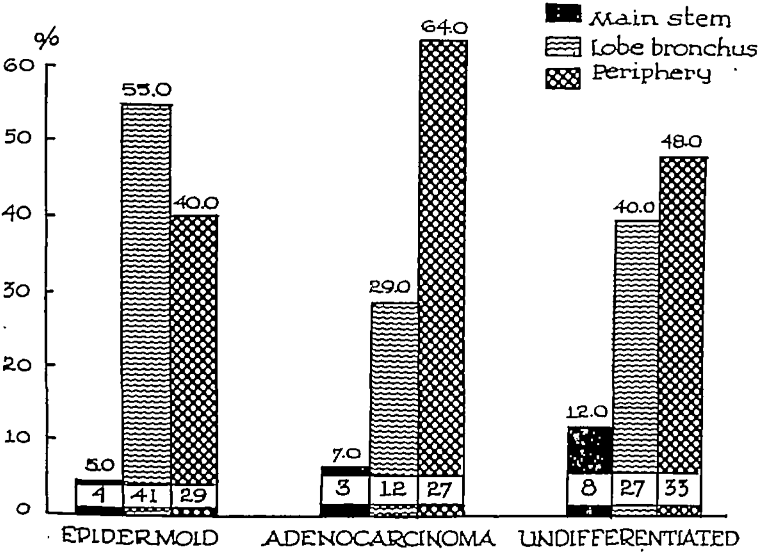

Fig. 12.—Distribution by location of lesion in the 190 cases of resection for carcinoma of the lung. The figures within the columns represent the number of cases and those above the columns represent percentage. Lesions designated as being in the "periphery" include all those originating distal to the primary bronchi.

Sex.—It has long been recognized that carcinoma of the lung is predominantly a disease of men, though no satisfactory explanation for this curious phenomenon has been advanced. In this series of 190 cases there were only 27 women (Fig. 16). Another interesting observation became apparent upon analysis of the sex distribution of our cases by histologic types. It was found that in men epidermoid carcinoma occurred more than two and one-half times more frequently than adenocarcinoma, but in women this ratio was completely reversed (Fig. 17).

Because of these differences in the relative incidence and types of carcinoma of the lung in the two sexes, it was considered desirable to determine the survival rates according to sex. The women showed a consistently more favorable prognosis over a five-year period than the men (Fig. 18). This may be explained in part by the fact that the average age of the women with resectable carcinoma of the lung was four years less than that of the men.

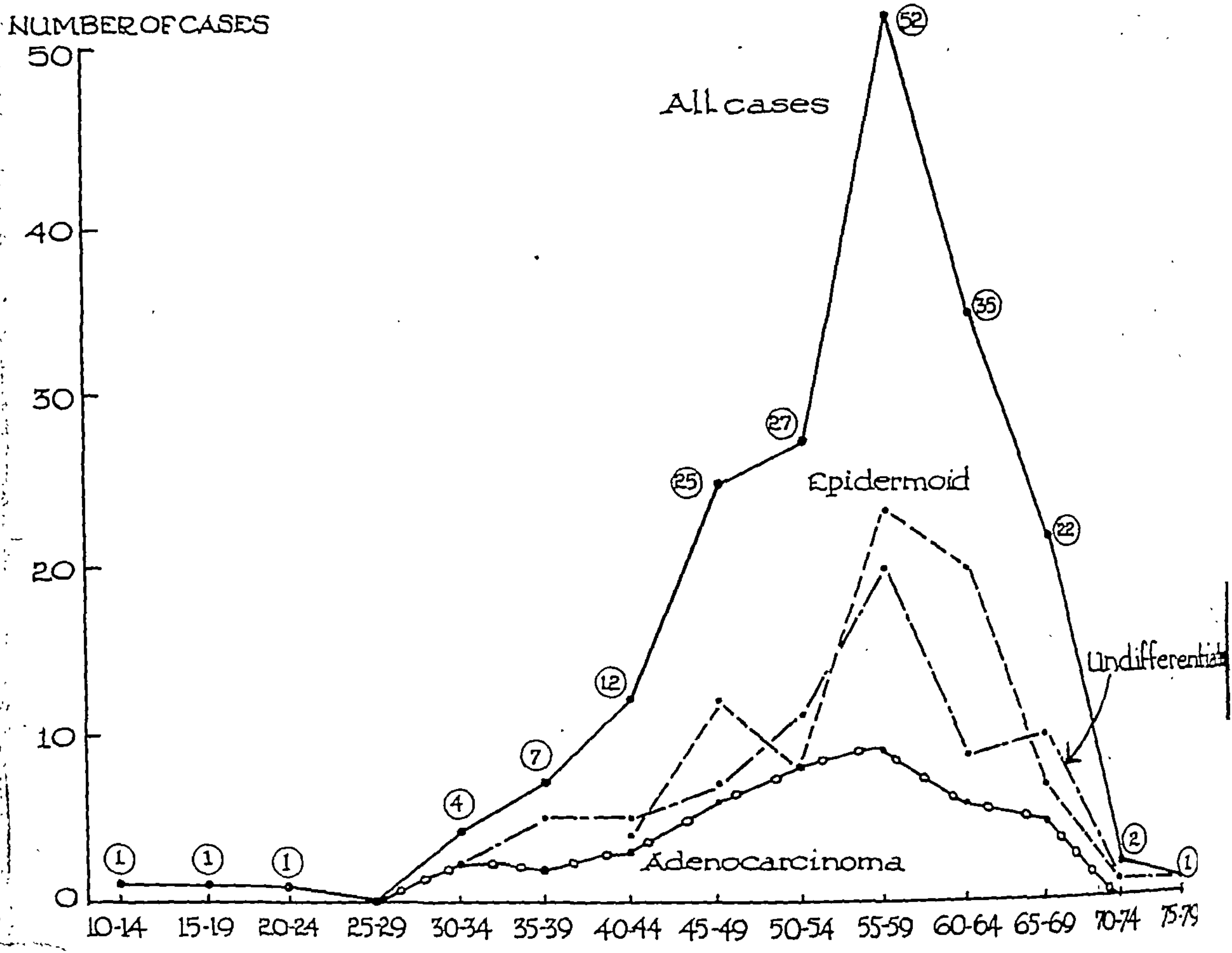

Fig. 13.—Age distribution by histologic types in the 190 cases of resection for carcinoma of the lung.

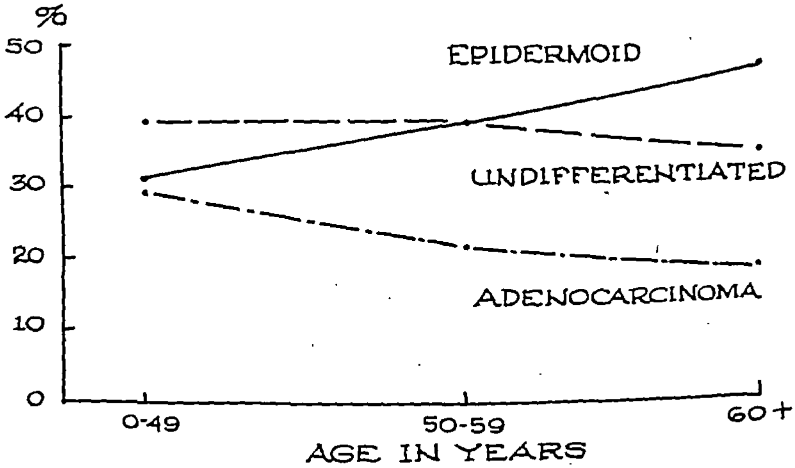

Fig. 14.—Incidence of histologic type according to age in the 190 cases of resection for carcinoma of the lung.

Survival by Histologic Types and Grades

The gross survival rate for the entire series of patients has already been presented. The patients were then studied in groups according to the histologic type of the tumors and the survival rate was computed for each group. The patients with epidermoid carcinoma showed the highest survival rate, undifferentiated carcinomas the lowest, whereas those with adenocarcinomas were intermediate (Fig. 19). Fatality rates were then computed according to the histologic grade of malignancy in each of the major histologic groups. Among

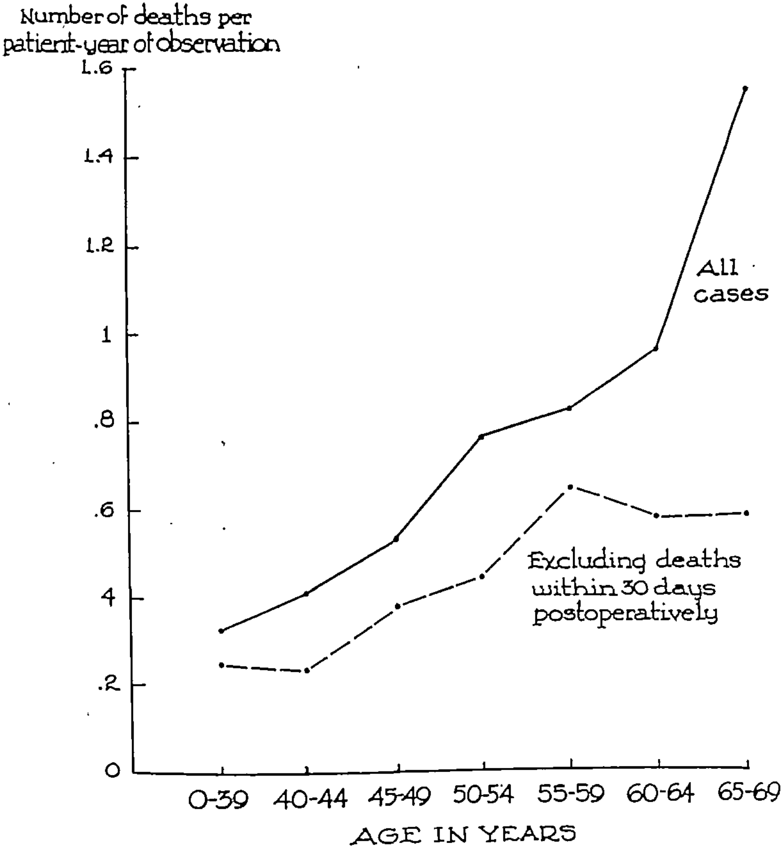

Fig. 18.—Fatality rates according to age at the time of operation in the 190 cases of resection for carcinoma of the lung.

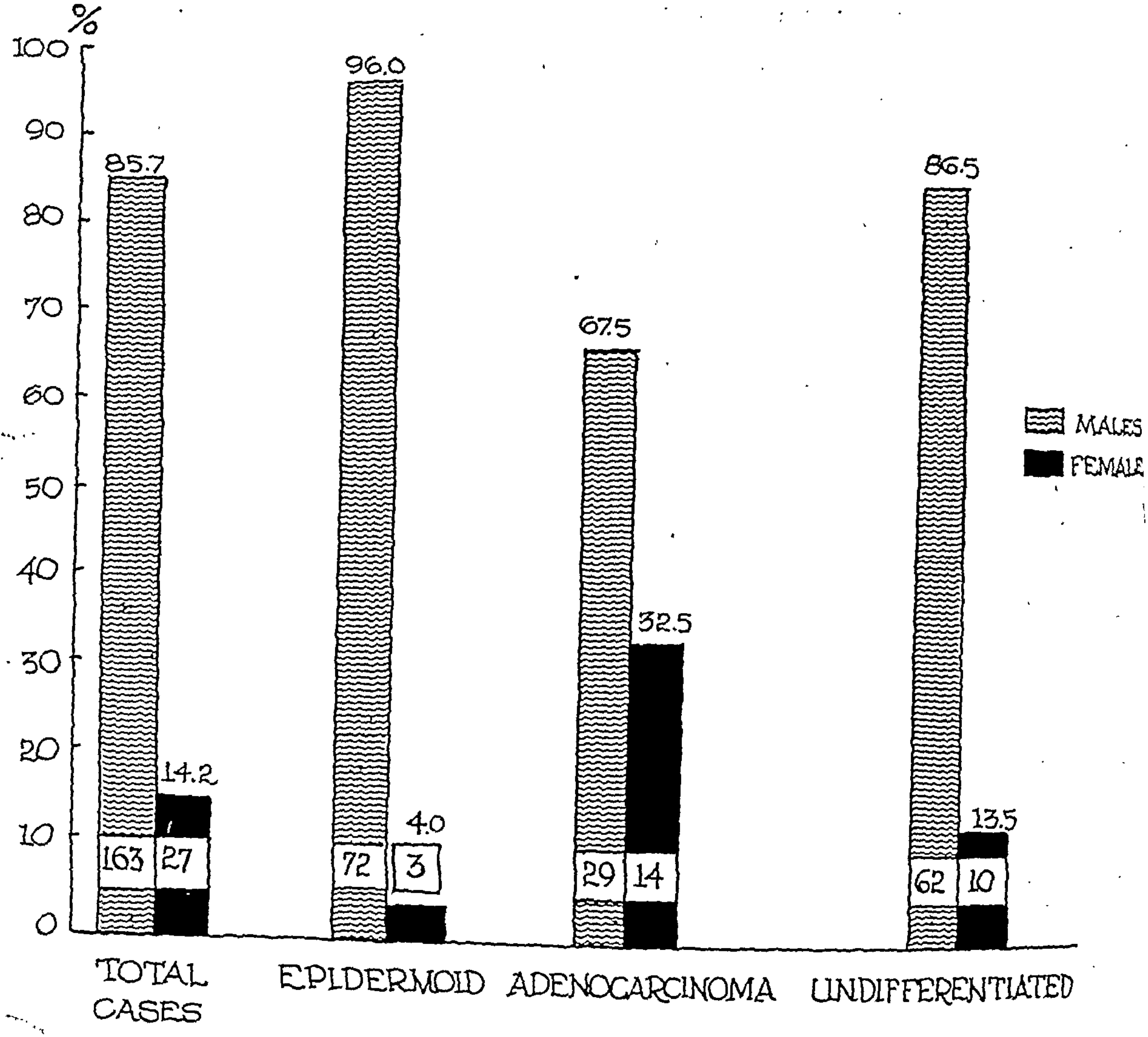

Fig. 16.—Sex distribution by histologic type in the 190 cases of resection for carcinoma of the lung.

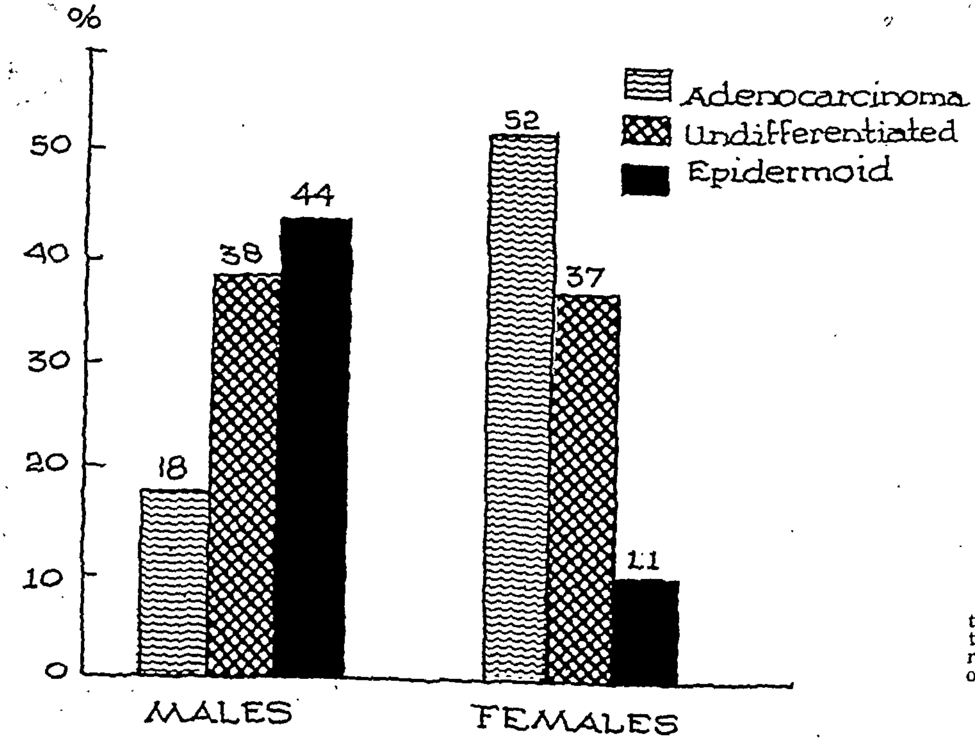

Fig. 17.—Sex distribution by histologic type in the 190 cases of resection for carcinoma of the lung.

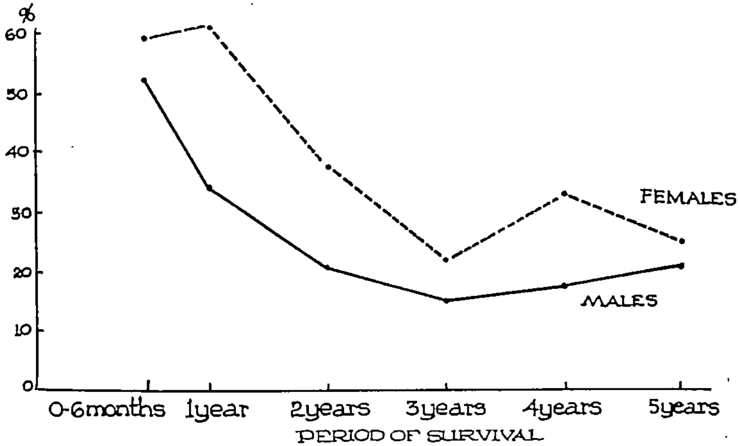

FIG. 18.—Survival rate according to sex in the 190 cases of resection for carcinoma of the lung.

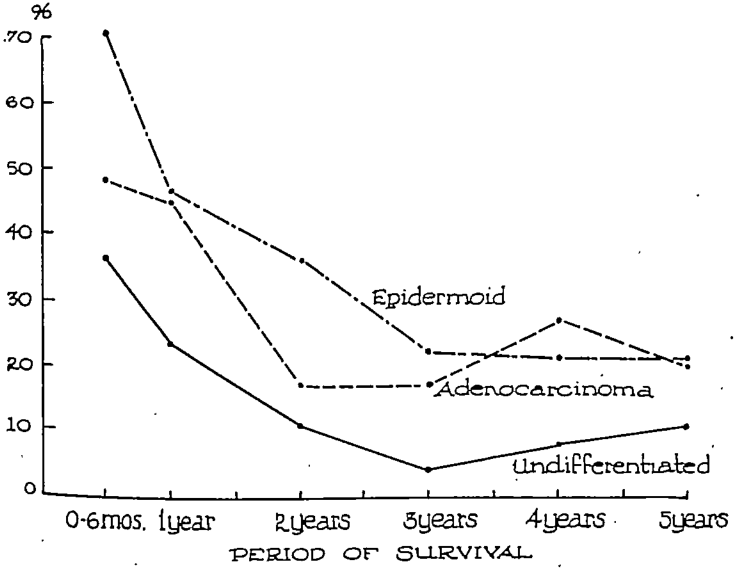

FIG. 19.—Survival rate according to histologic type in the 190 cases of resection for carcinoma of the lung.

the epidermoid carcinomas there was a progressive rise in the fatality rate from Grade I and II to Grade IV, which was apparent both in the palliative and the curative cases (Fig. 20). The same pattern was apparent among the different grades of adenocarcinoma (Fig. 21). Although the undifferentiated carcinomas were not graded, the small-cell and oat-cell tumors carried the lowest fatality, the miscellaneous group was next, and the large round- and clear-cell tumors gave by far the highest fatality rate of any group studied (Fig. 22).

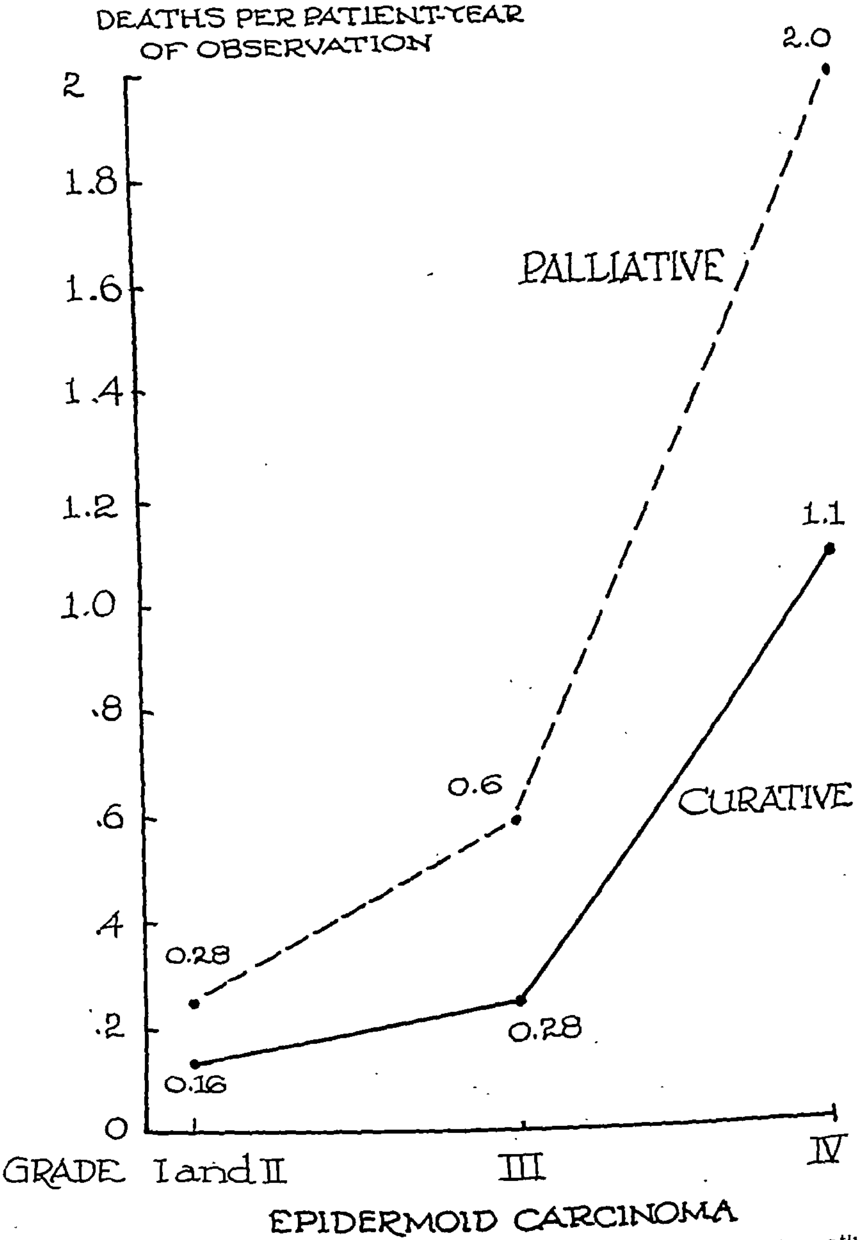

Fig. 20.—Fatality rate according to histologic grade in the 51 palliative and 24 curative resections of epidermoid carcinoma of the lung.

SUMMARY AND CONCLUSIONS

1. Among 548 patients with primary pulmonary malignancy, 194 (35.4 per cent) had inoperable lesions, 47 (6 per cent) refused operation, and 307 (56.1 per cent) had exploration. Of the 307 explorations, the lesion was found to be resectable in 195 (35.6 per cent of the total series). In brief, this means that of every three patients with carcinoma of the lung one had an obviously inoperable lesion, one had a lesion found to be inoperable at exploration (or refused operation), and one had a resectable lesion.

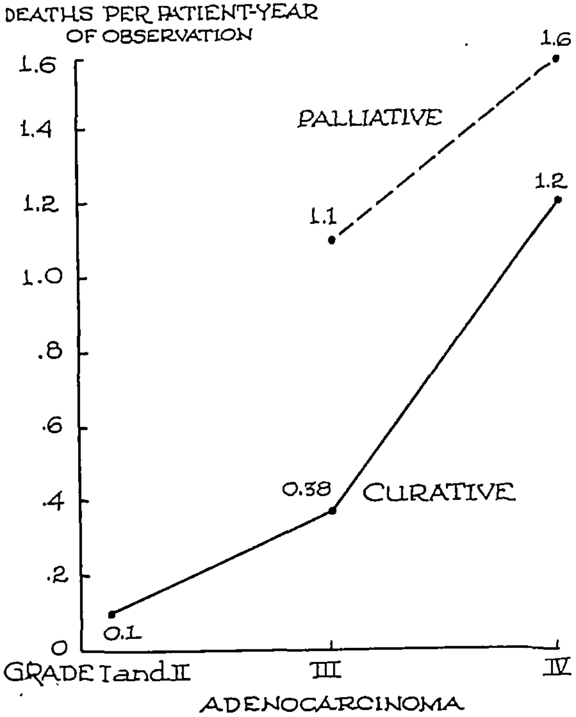

Fig. 21.—Fatality rate according to histologic grade in the 31 palliative and 12 curative resections of adenocarcinoma of the lung.

2. Positive results of bronchoscopic biopsy were obtained in only 37.9 per cent of the 195 cases of resection. In approximately the same proportion of cases, the lesions in the resected specimens were found to be within range of bronchoscopic visualization. This illustrates the diagnostic limitations of bronchoscopy and emphasizes the importance of exploration when all diagnostic methods yield only presumptive evidence of carcinoma.

3. Among the 195 cases of resection there were 45 hospital deaths. There has been a progressive reduction in hospital mortality during the period of this study from an initial figure of 54.5 per cent to 16.4 per cent. Approximately one-half of the hospital deaths were attributable to cardiovascular disturbances, one-quarter to respiratory disorders, and the remainder to hemorrhage and miscellaneous causes.

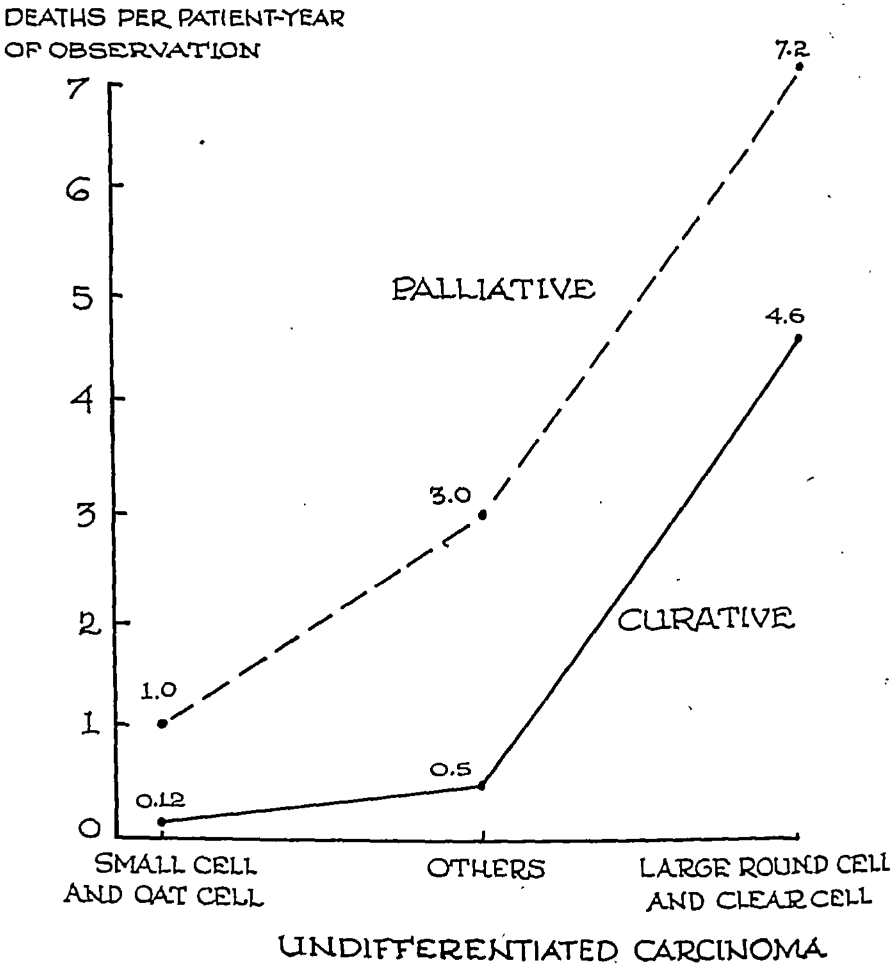

Fig. 22.—Fatality fate according to histologic type among the 53 palliative and 19 curative resections of undifferentiated carcinoma of the lung.

4. In this series, 70 per cent of the resections were considered palliative rather than curative since the lesions had extended beyond the confines of the lung. Palliative resections are considered justifiable because the risk is not excessive, the patient's remaining span of life is more comfortable, and the average survival period is increased.

5. In all but one of the 195 cases, the original slides were reviewed, classified, and graded without knowledge of the original diagnosis or fate of the patient. All carcinomas were placed in one of these groups: epidermoid (squamous cell) carcinoma, adenocarcinoma, or undifferentiated carcinoma. The epidermoid and the adenocarcinomas were divided into four grades of

histologic malignancy, and the undifferentiated carcinomas were arbitrarily divided into three subgroups according to cell type. Among the 195 cases of resection, carcinoma was found in 190, neurofibrosarcoma in 1, Hodgkin's disease in 1, lymphosarcoma in 1, malignant melanoma in 1, and 1 diagnosed as carcinoma at the time of operation was excluded because the original slides were not available. Among the 190 carcinomas, 75 were epidermoid, 43 adenocarcinoma, and 72 undifferentiated.

6. The gross survival rate after resection was 20 per cent at the end of three years with little change up to five years thereafter.

7. The survival rate in curative resections was considerably better than in the palliative group, but even in the latter a 10 per cent three-year survival rate was observed. Among the cases of nonresection, however, no patient survived three years.

8. Lesions in the right lung had a higher fatality rate than in the left lung. There was no difference in the fatality rates between centrally and peripherally located lesions.

9. Epidermoid and undifferentiated carcinomas occur in a higher proportion in the older age groups than do the adenocarcinomas. The distribution of histologic type is about equal among the younger age group, but among the older age group there is a preponderance of epidermoid carcinomas. With increasing age at the time of operation there is a progressive increase in fatality. A sharp increase in fatality occurs in patients operated upon after the age of 60 years.

10. Among the 190 patients with carcinoma of the lung there were 163 men and 27 women, a ratio of about 6 to 1. The most frequent type of tumor in men was epidermoid carcinoma whereas in women it was adenocarcinoma. The survival rate over a five-year period was consistently more favorable in women.

11. The most favorable survival rate was found in patients with epidermoid carcinoma and the poorest in those with undifferentiated carcinoma. Histologic grading of epidermoid and adenocarcinoma showed a good correlation with fatality. Among the undifferentiated carcinomas the small-cell and oat-cell tumors carried the lowest fatality and the large round- and clear-cell tumors the highest.

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CONGENITAL TRACHEOESOPHAGEAL FISTULA WITHOUT ESOPHAGEAL ATRESIA

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CONGENITAL tracheoesophageal fistula in the presence of an otherwise normal esophagus is of rare occurrence. Isolated reports of a congenital tracheoesophageal fistula as a sole entity are to be found in the literature, but most esophageal malformations consist of an esophageal atresia which is usually associated with a tracheoesophageal fistula. Largely because of its rarity, but partially because of difficulties in establishing the diagnosis of congenital tracheoesophageal fistula without esophageal atresia, the only reported instance of an attempt to correct the anomaly is the one described by Imperatori.[1] In his case, closure could be obtained through a cervical tracheotomy incision because of the high location of the fistula. In the following case an extrapleural approach was used for the closure of a congenital tracheoesophageal fistula situated within the thorax.

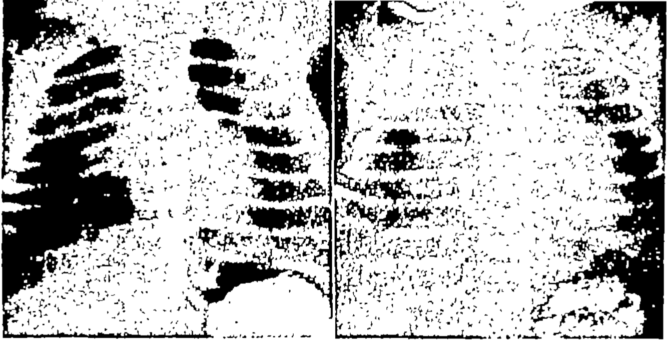
CASE REPORT

J. C. (No. 599481), male, aged 4 years, was referred to the University of Michigan Hospital on Sept. 16, 1946, by Dr. Duane Carr, Memphis, Tenn., who had established the diagnosis of congenital tracheoesophageal fistula without an esophageal atresia. The child presented symptoms of choking and cyanosis concurrent with feedings since birth. Because of the suspicion of congenital atresia of the esophagus, a catheter was introduced into the stomach on the second day after birth. Roentgenologic verification of the patency of the esophagus was obtained on the fourth day after birth, at which time barium was injected through a catheter (Fig. 1, *A*). On the twelfth day a barium suspension given orally revealed the contrast medium in the esophagus, trachea, and right bronchi (Fig. 1, *B*). It was presumed that the barium had entered the trachea by the supraglottic route and the diagnosis of tracheoesophageal fistula was not made at that time. Atelectasis of the upper lobe of the right lung was evident in the film studies on the twelfth day; the ensuing films of the chest at intervals during the next four years revealed varying degrees of bilateral pneumonitis (Fig. 2). At no time during this period were the lungs free of pneumonitis on roentgen examination. A chronic cough appeared shortly after birth; at times during the day, but more so at night, the cough was accompanied by choking and cyanosis. The symptoms occurred suddenly and with sufficient severity so that the mother had to be in constant attendance throughout the day and night; often it was necessary to invert the patient quickly in order to drain secretions from the bronchial tree.

Gavage feedings were begun on the second day after birth and were continued until the end of the first year of life when feedings were started by the oral method. The feedings often caused choking and coughing. As a result of these symptoms, vomiting frequently occurred during or shortly after meals. Solid foods were ingested more readily than liquids, and milk caused fewer symptoms than water. Because of the almost invariable choking on swallowing water, the child had an aversion to it and rarely drank it. During the period of four years, there had been seven attacks of pneumonia, and paracentesis of the m. tympani had been required on fourteen occasions because of bilateral otitis media.

From the Department of Surgery, University of Michigan Medical School.

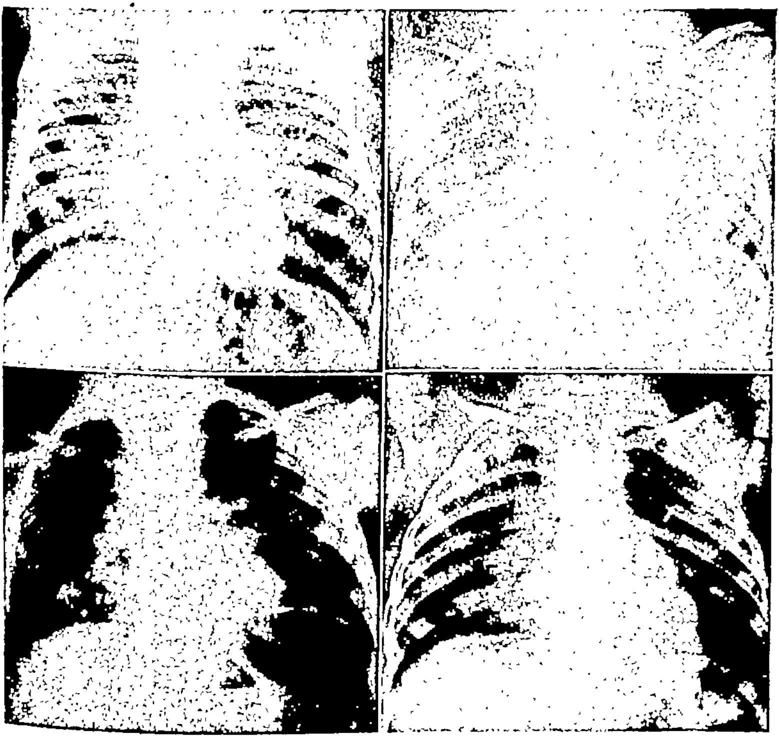
Read (by title) at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.



A.   B.

Fig. 1.—*A*, The absence of an esophageal atresia demonstrated by passage of a catheter into the stomach four days after birth. *B*, Roentgenogram following ingestion of barium twelve days after birth. The contrast medium in the trachea and bronchi was believed to have been aspirated through the larynx. (Courtesy of St. Joseph's Hospital, Memphis, Tenn.)

A.   B.



C.   D.

Fig. 2.—*A*, *B*, *C*, and *D*, Roentgenograms at age of 13 months, 2, 3, and 4 ye spectively, reveal the presence of varying degrees of bilateral pneumonit F Courtesy of Methodist Hospital, Memphis, Tenn.)

When the patient was 3¼ years of age he was seen in consultation by Dr. Carr. Since the mother mentioned at that time that the symptoms were more pronounced when the child was turned into the prone position, Dr. Carr suspected the presence of a tracheoesophageal fistula and suggested an examination of the esophagus with iodized oil and with the patient in the prone position. The oil entered the bronchial tree, outlining the trachea and both main bronchi, whereupon a diagnosis of congenital tracheoesophageal fistula was made. Operative correction of the fistula was advised but the parents did not accept this recommendation until nine months later.

On examination the child was well developed and well nourished in spite of the respiratory difficulties which had attended the feedings. The weight was 26 pounds. Respiratory wheezes were audible at a distance, and a frequent cough was productive of mucoid secretion. The nose and throat revealed evidence of an acute upper respiratory infection. The chest presented an emphysematous appearance; the breath sounds were harsh throughout and numerous râles were audible bilaterally, particularly at the bases of the lungs. The examination otherwise was not of interest. The laboratory examinations showed no deviations from normal.

Roentgenologic examination of the esophagus was made by Dr. John F. Holt on Sept. 17, 1946. Iodized oil was given orally with the patient in the *prone* position. It was observed by fluoroscopic examination that the oil entered the trachea coincident with the first swallow. The exact site of the fistula could not be determined at the fluoroscopic examination or in the subsequent films. There appeared to have been slight regression of the bilateral pneumonitis since the last preceding film studies nine months earlier. Operation was deferred for ten days after admission in order to await clearing of the acute upper respiratory infection. During this interval the child received sulfadiazine orally and penicillin intramuscularly.

Operation was done Sept. 27, 1946. Bronchoscopy, esophagoscopy, and repair of congenital tracheoesophageal fistula were carried out. After the induction of ether-oxygen anesthesia, the trachea was examined with a 4 mm. bronchoscope, but a fistula could not be seen. A 5 mm. bronchoscope was then used for examination of the esophagus. The anterior wall of the esophagus was carefully investigated, but no fistula could be found. Because the determination of the exact level of the fistula had not been possible on roentgenologic examination, and because it was believed that this information was of importance in planning the level of the operative approach, the tracheoscopy was repeated using a 5 mm. bronchoscope. The improved visibility of the trachea with this instrument resulted in the prompt recognition of a large fistulous opening on the right posterolateral wall of the trachea at a level approximately 1.5 to 2 cm. above the bifurcation. At a distance of several milimeters from the wall of the trachea, the lumen of the fistula narrowed to a diameter of 3 to 4 mm. Air and watery fluid bubbled through the fistula coincident with the expiratory phase of respiration, indicating a communication with the esophagus. The bronchoscope was withdrawn, an intratracheal tube was inserted, and the patient was then placed in the left lateral position.

The site of the incision was infiltrated with ¼ of 1 per cent solution of Metycaine hydrochloride. A right parascapular incision was made from the level of the second to the sixth ribs. The fourth and fifth ribs were resected posteriorly, the fourth intercostal muscle bundle was divided, and the parietal pleura was separated from the thoracic wall until the posterior mediastinum was entered. The esophagus and trachea were exposed and the vagus nerve was infiltrated with the local anesthetic solution. Between the lower portion of the trachea and the esophagus, a gap of about 3 mm. was present. At this level, a fistula was not evident between the two structures. The dissection was carried upward, and the tracheoesophageal fistula was encountered at a distance of about 2 to 2.5 cm. above the bifurcation. The length of the fistula was about 4 mm.; its breadth could not be ascertained until the areolar and fatty tissue adjacent to its superior edge had been reflected upward, whereupon it could be seen that the breadth was about 6 mm. A silk thread was passed around the fistula to provide traction (Fig. 3, *A*). It was apparent at this time that the exposure was insufficient to allow satisfactory closure of the fistula. The posterior portion of the third

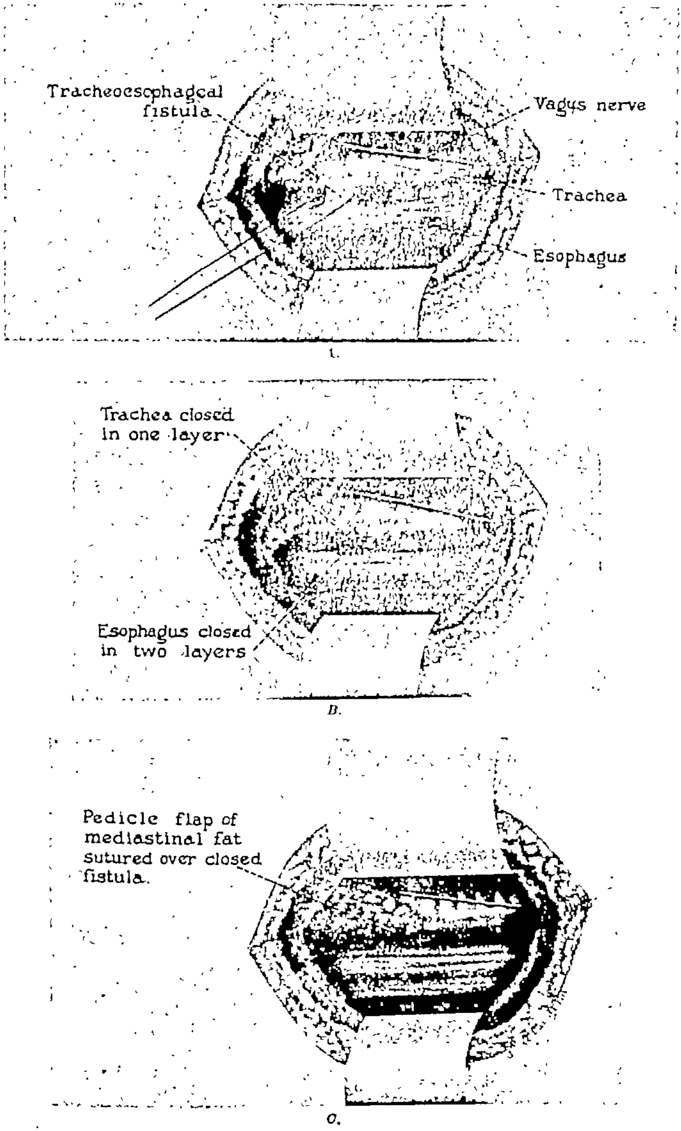
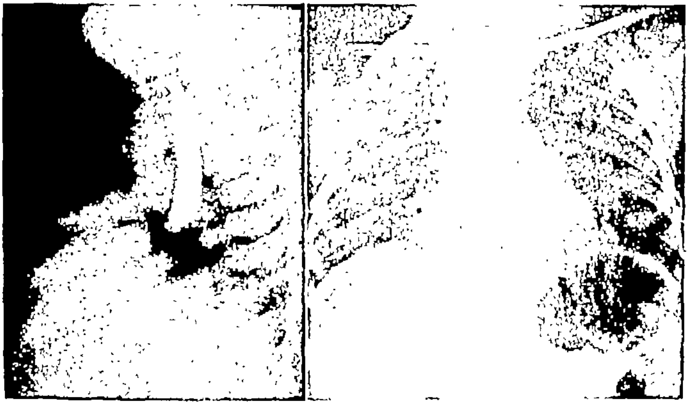

Tracheoesophageal fistula
Vagus nerve
Trachea
Esophagus
A.
Trachea closed in one layer
Esophagus closed in two layers
B.
Pedicle flap of mediastinal fat sutured over closed fistula.
C.

Fig. 3.—*A*, The appearance of the tracheoesophageal fistula as seen on extrapleural exposure of the anomaly. *B*, The fistula has been transected close to the esophageal wall. The tracheal opening has been closed with one layer of interrupted sutures and the esophageal opening with two layers of sutures. *C*, A pedicle flap of mediastinal fat and areolar tissue has been sutured over the closed tracheal fistula in order to reinforce the suture line and to interpose a barrier of tissue between the closed fistulas.

rib was therefore resected and the third intercostal muscle bundle posteriorly was divided between ligatures. The fistula was partially transected from below upward for a distance corresponding to about one-third of its breadth. As it was anticipated that closure of the tracheal end of the fistula would be more difficult than closure of the esophageal end, the incision was placed in close proximity to the esophageal wall in order to leave a cuff of the fistulous wall attached to the trachea. This plan was thought to be necessary in view of the relatively large diameter of the fistula as it entered the trachea, as had been observed during the tracheoscopic examination. On incision of the fistula, it appeared that the horizontal diameter of the tracheal opening was slightly greater than the vertical diameter. In spite of the cuff of the fistulous wall which had been preserved, some difficulty was experienced in the placement of sutures along the inferior margin of the tracheal end of the fistula. This condition resulted from the fact that a portion of the fistulous opening extended lateral to the membranous portion of the tracheal wall and arose from the rigid cartilaginous wall. The fistula was then completely transected, and the tracheal opening was closed with approximately six sutures of interrupted 00000 silk on atraumatic needles. The opening into the esophagus was readily closed with sutures of a similar material; the first layer of sutures of an end-on mattress type was placed in the mucosa and a satisfactory inversion of its edges was obtained. The longitudinal fibers of the muscularis, which had been displaced laterally by the presence of the fistula, were then approximated to provide for a second layer of the closure (Fig. 3, *B*). In order to strengthen the closure of the tracheal end of the fistula and to interpose a layer of tissue between the tracheal and esophageal suture lines, a pedicle flap of the mediastinal fat and areolar tissue which had been displaced upward on exposing the fistula was sutured downward to cover the tracheal suture line (Fig. 3, *C*). The wound was irrigated with physiologic saline solution and 200,000 units of penicillin were instilled. As a small opening had been made in the mediastinal pleura immediately behind the junction of the azygos vein with the superior vena cava, the inner end of a narrow gauze drain was placed over the site of the pleural opening. The outer end was brought out through the central portion of the incision. Inflation of the lung was maintained with positive pressure during the closure. The anterior ends of the divided intercostal muscles were sutured to the undersurface of the sacrospinalis muscle, the extracostal muscles were approximated in layers, and the subcutaneous tissues and skin were closed in separate layers. During the operation the patient received 200 c.c. of blood by infusion into the saphenous vein at the level of the left ankle. Examination of the chest at the conclusion of the operation revealed breath sounds of normal intensity throughout the right lung and no evidence of pneumothorax.

The postoperative course was satisfactory and without complications. A Levine tube was placed into the stomach to prevent gastric distention and vomiting, but constant suction was not necessary. Fluids were administered by subcutaneous infusion and rectal instillation for the first two days after operation and were then given by gavage from the third to fifth days, inclusive. Fluoroscopic examination with the aid of iodized oil and with the patient in the prone position on the fifth day revealed no evidence of leakage of the esophageal suture line, and oral feedings were begun on the following day. Penicillin by intramuscular injection was continued throughout the postoperative course, and sulfadiazine was begun on the third day coincident with gavage feedings. The gauze drain in the extrapleural wound was shortened daily and was completely removed on the sixth postoperative day. Film studies of the chest on the first and second days revealed increased density in the extrapleural wound space, but no effusion was present in the right pleural cavity. An examination of the esophagus with barium on the twelfth day showed no abnormality (Fig. 4, *A*). At this time the pneumonitis in the right hilar region had decreased, but the pneumonitis in the left lung remained unchanged. The patient was discharged from the hospital on the thirteenth day; the wound was healed, feedings were being taken without symptoms, and the chronic cough which had been present before operation had almost completely disappeared. There was a complete absence of the râles which had been present throughout both lung fields on admission.

A roentgenogram of the chest five weeks after operation showed considerable clearing of the pneumonitis bilaterally (Fig. 4, *B*). The patient had no symptoms after his return home. The complete disappearance of the cough was particularly gratifying, inasmuch as it had been suspected that an irreversible bronchiectasis might have developed as a result of the prolonged pneumonitis. Reports from the parents at intervals during the eight months which have elapsed since operation state that the patient continues to have no symptoms.



A. *B.*

Fig. 4.—*A*, Roentgenogram twelve days after closure of tracheoesophageal fistula. *B*, Considerable clearing of the bilateral pneumonitis is evident five weeks after operation. (Courtesy of Dr. J. Cash King, Memphis, Tenn.)

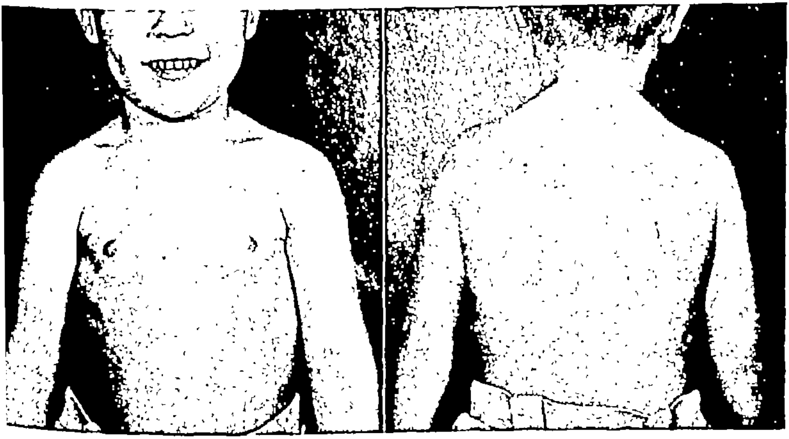


Fig. 5.—Photograph of patient five months after operation.

DISCUSSION

The large majority of congenital esophageal malformations consist of an atresia which is usually associated with the fistulous communication between the trachea and lower esophageal segment. Less often an atresia of the esophagus with varying degrees of agenesis of the lower esophageal segment and without a tracheoesophageal fistula is seen. During the past twelve years, sixty-three infants with atresia of the esophagus have been observed at the University of Michigan Hospital. In contradistinction to the frequency of esophageal atresia, only two patients have been seen with congenital tracheoesophageal fistula in the presence of an otherwise normal esophagus. One of these patients has been referred to in previous publications[2, 3] and has been illustrated by Patten.[4] The other case is the subject of the present report. The incidence of tracheoesophageal fistula as a single entity, as contrasted with the incidence of esophageal atresia, in the cases seen personally to date is approximately 3.0 per cent.

Evidence of the rarity of congenital tracheoesophageal fistula without other abnormalities of the esophagus is substantiated by a review of the literature, although discrepancies are to be found in the earlier reports of this anomaly. Cautley[5] in 1917 referred to six instances of tracheoesophageal fistula without other esophageal abnormalities in the cases of congenital anomalies of the esophagus reported previous to that date. Two years later, Plass[6] was able to find only one case of congenital tracheoesophageal fistula in 136 reported cases of malformations of the esophagus. Cautley and Plass agree in their citation of the case reported by Lamb[7] in 1873 that it was a case of congenital tracheoesophageal fistula. It has likewise been possible for me to verify the authenticity of this case, which appears to have been the first case of congenital tracheoesophageal fistula unassociated with other abnormalities of the trachea or esophagus to be reported in North America. The case of Eppinger's,[8] mentioned by Cautley as a congenital tracheoesophageal fistula and not included in the cases collected by Plass, has been found to be a congenital tracheoesophageal fistula situated just above the bifurcation of the trachea. The esophagus showed no other abnormality. Another case included by Cautley as a case of congenital tracheoesophageal fistula, but mentioned by Plass as a case of congenital atresia of the esophagus with tracheoesophageal fistula, is one described by Vrolik.[9] Eppinger described this case as having a narrow but passable area in the upper esophagus and a tracheoesophageal fistula above the stenosis. The case described independently by Pinard[10] and by Tarnier[11] was mentioned by Cautley as a case of congenital tracheoesophageal fistula and by Plass as a case of congenital atresia of the esophagus. On consulting the original references this case has been found to have had a high tracheoesophageal fistula situated immediately below the glottis. The esophagus was otherwise normal. Richter's[12] case, included as a case of congenital tracheoesophageal fistula by Cautley, is mentioned by Plass as being a peculiar abnormality whereby the trachea and esophagus formed a single sac. I have not been able to locate the original descriptions of this case and the one of Von der Water's[13] which is mentioned by Cautley as a tracheoesophageal fistula and is not included in the cases collected by Plass.

More recent reports of congenital tracheoesophageal fistula are described by Imperatori[1] and by Gengenbach and Dobos[14] (two verified cases and one presumptive case), and additional cases are mentioned by Leven and Lannin[15] (two cases), Shaw[16] (one case), and Barkley[17] (one case). The patient operated on by Imperatori was the only one for whom operation has been undertaken to correct the anomaly. In view of the fact that approximately 500 cases of congenital atresia of the esophagus have been reported to date, it is apparent that the incidence of congenital tracheoesophageal fistula as a sole entity is rare.

The symptoms of congenital tracheoesophageal fistula unassociated with other anomalies of the esophagus consist of choking and coughing coincident with the ingestion of feedings and particularly with the ingestion of liquids. In the case described in this article, the symptoms occurred especially during the ingestion of water. This finding was also observed by Clerf, Cooley, and O'Keefe[18] in an adult with an acquired esophagobronchial fistula. These symptoms occurring in relation to feedings appear to vary inversely with the viscosity of the feedings. Similar symptoms, often associated with cyanosis and at times respiratory arrest, may occur after a variable interval following feedings. Such symptoms are usually the result of regurgitation of feedings and their sudden entrance into the tracheobronchial tree in large amounts. The delayed symptoms following meals are more likely to occur if the infant is in a prone position, inasmuch as this position causes the fistula to be dependent in its relation to the esophagus and thereby facilitates the entrance of esophageal contents into the trachea. A chronic wet cough and fever occur as a result of a pneumonitis which develops sooner or later because of the repeated aspiration of foreign material into the tracheobronchial tree.

In newborn infants the symptoms of congenital tracheoesophageal fistula are not unlike those resulting from a faulty neuromuscular coordination of the act of deglutition. In both these conditions the infant can swallow a normal amount of the feeding providing the symptoms are not too severe. It is important, therefore, that these two conditions be differentiated from each other by appropriate examinations to determine the presence or absence of a fistula. If the symptoms of congenital tracheoesophageal fistula are severe, they may simulate the more common anomaly of congenital atresia of the esophagus with tracheoesophageal fistula. The diagnosis of esophageal atresia can be readily ascertained by the detection of the atresia on roentgen examination of the esophagus with the aid of a catheter or iodized oil, or the absence of an atresia can be determined by the ability to pass a catheter into the stomach.

Leven and Lannin have remarked that the symptoms of congenital tracheoesophageal fistula may be inconstant because of the small size of the fistulous track and that the diagnosis may be difficult to establish before autopsy. Unlike esophageal atresia with tracheoesophageal fistula, the symptoms of congenital tracheoesophageal fistula may not be of sufficient severity to prompt an early diagnosis. As the infants may be able to maintain their nutrition, the condition may continue to remain unrecognized and untreated, masquerading under the impression of an acute recurring pneumonitis or a faulty mechanism of deglutition. In the patients with congenital tracheoesophageal fistula who have survived more than a few days, a recurring pneumonitis has been the reason for the frequent periods of hospitalization.

The length of life has varied considerably in the patients for whom operation has not been done. The shortest survival was the case described by Pinard and Tarnier in which death occurred thirty-six hours after birth and followed the operative repair of an imperforate anus. One of the patients described by Gengenbach and Dobos lived four days. Barkley's and Shaw's patients died at the age of 5 and 13 days, respectively. Lamb's patient was 7 weeks of age at the time of death. The first patient seen in the University of Michigan Hospital died at the age of 3 months. Another of the patients described by Gengenbach and Dobos was 2 years old at the time of their report and a third patient of theirs, in whom the diagnosis was suspected but not definitely established, was 8 months of age when reported. Eppinger's case was that of a "young man" whose age at the time of death was not specified. The two patients for whom operation was done were 4 years of age (the case reported in this article) and 6½ years of age (Imperatori's case) at the time of their respective operations.

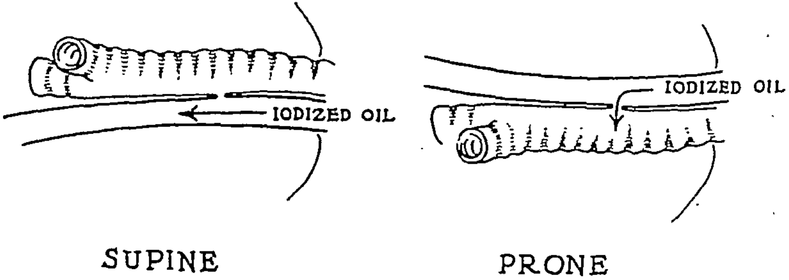


Fig. 6.—The roentgen diagnosis of congenital tracheoesophageal fistula may not be apparent if the patient is in the supine position. The prone position causes the fistula to be dependent in its relation to the esophagus, thereby allowing the iodized oil to enter the trachea by gravitation.

The diagnosis of tracheoesophageal fistula without esophageal atresia has been difficult to establish in the cases reported to date. This has been true even when the anomaly has been suspected. The diagnosis should be readily evident, however, if certain precautions are observed in the roentgenologic examination or if endoscopic examination of the trachea or esophagus or both is performed. In the first patient seen in the University of Michigan Hospital, fluoroscopic and roentgenographic examinations of the esophagus were carried out on two successive days because of the suspicion of tracheoesophageal fistula and the inability to confirm the diagnosis at the first examination. These examinations were made with the patient in the supine position in which the fistula was nondependent in its relation to the trachea. On both examinations there was no evidence of entrance of the iodized oil into the trachea. In view of these negative examinations, endoscopic examination was not done, and the diagnosis was not made until the post-mortem examination, when it was obvious that the fistula should have been detected had the fluoroscopic examinations been made with the infant in a prone position. The importance of roentgenologic examination with the patient in the prone position in cases of suspected tracheoesophageal fistula, either of the uncomplicated congenital type or of the acquired type secondary to a repair of a congenital atresia of the esophagus with tracheoesophageal fistula, has been stressed by Holt, Haight, and Hodges.

A suggestive but not diagnostic roentgenologic sign in infants with tracheoesophageal fistula but without esophageal atresia is the presence of an unusually large amount of air in the stomach or intestines. This finding was noted by Lamb, who mentioned that the most prominent symptom in his case was "flatulence which was abundant and very painful." Although the presence of a large amount of air in the stomach is entirely physiologic in newborn infants, the amount of air observed in our first patient with tracheoesophageal fistula alone was greater than in any of the patients with esophageal atresia associated with a tracheoesophageal fistula.[4] In several patients who have undergone repair of an esophageal atresia with a tracheoesophageal fistula, the appearance of gastric dilatation has been observed coincident with the development of a recurrent tracheoesophageal fistula. The gastric dilatation becomes evident when the infant cries or strains, appearing to be due to an increase of intratracheal pressure in the presence of a closed glottis and the expulsion of air into the esophagus and stomach. It must be assumed that there is simultaneous closure of the cricopharyngeus muscle at the entrance of the esophagus during crying or straining, inasmuch as the air is forced downward into the stomach, rather than being expelled through the mouth.

The diagnosis of congenital tracheoesophageal fistula has been made by endoscopic examination in two of the previously reported cases. In the patient described by Imperatori the diagnosis was established first by C. L. Jackson during bronchoscopic examination when the patient was 6 years, 5 months of age. Tracheoscopic and esophagoscopic examinations have been employed by Holinger to establish the diagnosis in one of the cases reported by Gengenbach and Dobos. In cases with a suspected congenital tracheoesophageal fistula, more frequent use of this diagnostic method should be made. Should there be difficulty in identifying the fistula, the bronchoscopic examination should be repeated after a preliminary swallow of a colored solution, such as methylene blue, as suggested by Abbott.[19]

A tracheoesophageal fistula of congenital origin should be corrected by appropriate measures as soon as the diagnosis has been made. The pneumonitis that is usually present is an urgent indication for, rather than a contraindication to, surgical treatment. This conclusion has been arrived at as a result of personal instances of recurrent tracheoesophageal fistula in the presence of a patent esophagus following the repair of a congenital esophageal atresia with an associated tracheoesophageal fistula. In one such patient who had lived to the age of 25 months, operation had been deferred pending an improvement of the pneumonitis. This did not occur and the patient died of the pulmonary complication. In view of this experience, the surgical closure of the fistula in the case reported in this article was done in spite of the pneumonitis, inasmuch as it was believed that the only satisfactory method to cure the pneumonitis was to eliminate its cause.

The successful closure of acquired fistulas between the esophagus and the trachea or bronchi in adults has been reported by several authors. Judd, Clagett, Havens, and Moersch[20] used a cervical incision for the closure of a high tracheoesophageal fistula resulting from a bullet wound. Adams and Mabrey[21] employed a transthoracic approach for a low tracheoesophageal fistula following a nonpenetrating crushing injury. Clagett, Payne, and Moersch[22] have reported the transthoracic closure of an acquired esophagobronchial fistula in an adult with calcified lymph nodes in the vicinity of the fistula. Clerf[23] and Clerf, Cooley, and O'Keefe[18] have successfully used beads of silver nitrate or sodium hydroxide crystals fused to a carrier and applied through an esophagoscope for the closure of esophagobronchial fistulas in adults. In the case reported in this article, operative correction was elected in preference to the use of a caustic because of the need for a prompt and definitive result in view of the existing pneumonitis and because of uncertainties regarding the satisfactory application of a caustic through a small esophagoscope. Although operative correction had been planned at the time of the endoscopic examinations, it was believed, furthermore, that the size of the fistula as observed during tracheoscopy was so relatively large in comparison with the size of the trachea, that chemical closure of the fistula would have presented less chance of success than that obtained by operation.

The surgical approach to intrathoracic tracheoesophageal fistulas is readily possible by either an intrapleural or an extrapleural exposure of the anomaly. The extrapleural route was favored in the case presented in this article because of the possibility of postoperative leakage of the suture lines and the lessened chance of contamination of the pleural space should leakage occur. Simple ligation of the fistula in continuity was deemed inadvisable in view of the ease with which a ligature will cut through a fistula, re-establishing its patency. This occurrence has been observed by Ladd[24] and by Leven and Lannin in patients with congenital esophageal atresia and tracheoesophageal fistula for whom ligation of the fistula was done. Division of the fistula between ligatures was considered inadvisable for the same reason. The preferable method was believed to be a transection of the fistula and closure of the openings with sutures.

The important technical factors in the transection and closure of a tracheoesophageal fistula are the use of suture material of fine size, the preservation of a cuff of ample length on the tracheal side of the fistula, and the use of a pedicle flap of tissue which supports the tracheal closure and serves as a barrier between the closed fistulas. The suture material of preference is fine arterial silk on atraumatic needles. Because of the rigidity of the tracheal wall, closure of the opening into the trachea is more difficult than closure of the esophageal opening. An intentionally long fistulous cuff should be left attached to the tracheal side of the fistula, if possible, to prevent tension upon the suture line. This was accomplished in the case reported in this article by dividing the fistula close to its esophageal end. Even so, the length of the cuff permitted the insertion of only a single layer of sutures. In this case, it would have been preferable to have divided the fistula flush with the esophagus so that the tracheal cuff would be of maximal length. Should the tracheal and the esophageal walls be in intimate contact above and below the fistula, as was determined at autopsy in the first patient seen in this hospital and for whom operation was not undertaken, a cuff could be fashioned by a circular incision through the esophageal wall adjacent to the fistula, thus leaving this portion of the esophageal wall attached to the trachea. The closure of this cuff should facilitate the closure of the tracheal opening without tension; the ample size of the remaining esophageal lumen and its ready distensibility should not cause sufficient narrowing to produce symptoms. The esophageal closure is readily accomplished because of the laxity of the esophageal wall, the ease with which the mucosa can be inverted, and the availability of the muscularis as a second layer of closure. A pedicle flap of mediastinal fat and areolar tissue is advantageous in buttressing the tracheal closure. Without the use of a pedicle flap, the closed fistulas remain in proximity to each other and should leakage of one occur, there is considerable likelihood of opening of the other with a resulting recurrence of the tracheoesophageal fistula. Drainage of the extrapleural wound is considered advisable in view of potential contamination, inasmuch as an aseptic method of closure is not attempted.

SUMMARY

Congenital *tracheoesophageal fistula without an associated atresia of the* esophagus is of rare occurrence, having been observed in approximately 3 per cent of a series of sixty-five cases of anomalies of the esophagus observed at the University of Michigan Hospital. The diagnosis may not be apparent on roentgen examination with a contrast medium, unless the examination is carried out with the patient in a prone position. Tracheoscopy, esophagoscopy, or both should be used in cases in which the anomaly is suspected. Because of its rarity and past difficulties in establishing the diagnosis, operative correction has been employed in only one previously reported patient. The case of a 4-year-old child for whom the fistula was transected and the tracheal and esophageal openings were closed by suture is presented.

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SPONTANEOUS RUPTURE OF THE ESOPHAGUS

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PERFORATION of the esophagus for any reason or at any level is always a grave lesion and one which potentially, at least, is very dangerous to life. So universally pessimistic has the outlook been that even as late as 1939 Wagner[72] was quoted for the following statement: "This tragic fate (death from esophageal perforation) can almost never be averted by surgical intervention, even if the surgery is carried out by the most skillful surgeon." Little difficulty is ordinarily encountered in making the diagnosis of perforation of the esophagus from foreign body or following instrumentation because of the antecedent history, while modern experience has amply demonstrated that prompt surgical intervention[55] plus chemotherapy and proper handling may save the lives of the majority of these unfortunates.

Spontaneous rupture or perforation of the esophagus is more dramatic in its onset and considerably more tragic in its outcome than the smaller perforations, because of the size of the opening, the widespread contamination, the shock, pulmonary collapse, emphysema, and tension pneumothorax which follow it. It is all the *more lethal because the origin of the difficulty is almost never suspected* as there is usually nothing to suggest an esophageal lesion, and the patient is frequently in such desperate condition as to be unable to tolerate any surgical procedure even if recommended.

The clinical picture of spontaneous rupture of the esophagus is one which is not generally recognized. The majority of the cases thus far reported in the literature, now more than fifty, have not been diagnosed before death, and in many instances not even suspected before the post-mortem examination, yet the clinical picture is so characteristic that in at least two instances (Wangensteen[74]) and our Case 5 (T. J. K.) the correct diagnosis has been made over the telephone. Since the first classical description of the condition, by Boerhaave[9] published in 1724, the case of Baron de Wassenaer, Grand Admiral of Holland, there have been a number of isolated reports of the occurrence of this condition. Excellent collective reviews have been made by Fitz[22] in 1877, McKenzie[44] in 1884, Walker[73] in 1914, Smead[66] in 1931, Girard[24] in 1934, Ridgway and Duncan[61] in 1937, Terracol and associates[69] in 1938, and in the excellent articles by Barrett[4] in March of 1946, and Eliason and Welty[21] in August, 1946, to which the reader is referred. Since that time additional cases have been reported by Foggitt,[23] Cummings,[16] Culver and Clark,[15] and an additional case by Barrett,[5] to which we can add five cases which have come under our observation.

The clinical picture in spontaneous rupture of the esophagus may vary slightly, but seems to follow rather characteristic lines. An apparently healthy

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individual (males 84 per cent), frequently robust and a notoriously heavy eater, often addicted to the use of alcoholics, suddenly begins to vomit, spontaneous or induced, sometime after eating a large meal, and suddenly develops excruciating pain, usually described as epigastric, extending through the left side of the chest to the back, followed by collapse and shock, and soon by dyspnea and cyanosis. The vomiting may continue but usually ceases and the patient develops marked thirst. Frequently emphysema (60 per cent) of the tissues at the base of the neck appears early though it may be somewhat delayed. The pain is intense, persistent, and does not respond to large doses of morphine. Occasionally there is no history of a preceding large meal, the vomiting occurring because of a neurogenic lesion, postoperative nausea, or some other condition. Sometimes there is no true vomiting, merely severe and repeated retching or rarely still there is no vomiting or retching whatsoever, perforation occurring apparently as a primary condition[61] as in Case 5. The material ejected during vomiting or retching may be food or dark brown "coffee-ground" material, occasionally associated with a small amount of blood and more rarely with free bleeding. A few of the patients present a history of previous ulcer of the stomach or duodenum[20] as Cases 1, 3, and 4; a small number have a history of mild dysphagia and substernal distress suggestive of esophagitis or esophageal ulcer, while four cases, 50, 66, 71, 77, have presented a previous history of esophageal stricture, with impaction of a bolus of food at the stricture site, the perforation occurring during a strenuous attempt to force the food past the narrowed area.

When first seen the patient is usually weak and pale, though he may be cyanotic. He is usually suffering severely, is bathed in cold perspiration, and frequently is unable to lie down. Respiration is rapid and labored, the pulse fast and weak, the temperature subnormal, and the blood pressure low. Emphysema may be present at the base of the neck, but may not develop until sometime afterward. There is frequently rigidity of the upper abdomen but not of the lower, but no tenderness or rebound tenderness.

Physical examination of the chest may be reported as negative, but frequently the findings of a pneumothorax with fluid on one or both sides, more frequently the left, may be elicited, increasing as the time following perforation increases. Almost invariably present, but frequently overlooked because only the anterior part of the chest is examined, or because the examination is not carried out in the erect position, because of the patient's serious illness, is a fluid level which may be percussed out or the succussion splash demonstrated by shaking the patient. Displacement of the heart and mediastinal structures, distant heart tones, and loss of substernal dullness as evidence of tension pneumothorax are frequently overlooked or unrecognized. The deviations of the trachea normally evident to palpation in the suprasternal notch may be obscured by the subcutaneous emphysema.

The differential diagnosis must include perforated peptic ulcer of stomach or duodenum, acute pancreatitis, mesenteric thrombosis, dissecting aneurysm of the aorta, coronary thrombosis, and perhaps pulmonary embolism and spontaneous pneumothorax from other sources. The diagnosis is most frequently missed because the physician is unfamiliar with the condition and gives no thought to the possibilities of such a catastrophe. Meyer[30] in 1858 is credited with having made the first clinical diagnosis of the condition. Since that time apparently less than 25 per cent of the cases have been correctly diagnosed before death[4, 5, 7, 14, 16, 21, 22, 30, 73, 74] and three of ours, Cases 3, 4, and 5.

The most frequent misdiagnosis encountered in the reported cases has been that of ruptured peptic ulcer which has been made many times and at least thirteen exploratory laparotomies carried out,[2, 4, 22, 33, 43, 57, 59, 66, 73, 76, 78] including our Case 1. Mediastinal emphysema presenting in the cervical region has been present in more than 60 per cent of the reported cases and cannot be produced by any of the other conditions listed in the differential diagnosis except possibly primary spontaneous pneumothorax, and occurs but rarely in that. The presence of hydropneumothorax, either unilateral, usually the left, or bilateral,[4, 8, 16, 19, 28, 42, 45, 50, 62] has occurred in all but seven of the reported cases,[1, 21-23, 43, 63] and cannot be produced by any of the conditions mentioned in the differential diagnosis except primary spontaneous pneumothorax, and should give a clue as to the exact condition. Pain, collapse, vomiting, hydropneumothorax, and emphysema should permit a diagnosis on historical and physical grounds alone if the clinician is cognizant of the occurrence of such a condition.

Several laboratory aids may establish or confirm the diagnosis and of these the x-ray examination is of greatest value. The earliest finding on x-ray films, probably present in all cases from the onset, if recognized, is the presence of emphysema in the mediastinum, localized at first, later more extensive, involving the whole mediastinum, and eventually fanning out as subcutaneous emphysema in the cervical region. The second important finding is the demonstration of a fluid level in the mediastinum; the third, the finding of a pneumothorax on one or both sides, most frequently on the left; and fourth, the demonstration of a fluid level within this pneumothorax pocket. A demonstration of the second and fourth of these findings, of course, requires that the films be made with the patient in proper position, usually erect so that the fluid level may be demonstrated. A fifth x-ray finding of negative diagnostic importance is, of course, the absence of subphrenic air or gas indicative of perforation of a subphrenic hollow viscus. The absence of this finding, of course, does not rule out subdiaphragmatic perforation as it is demonstrable in only 70 to 80 per cent of proved gastric and duodenal perforation. If further evidence of perforation of the esophagus is required it may be obtained by demonstration of orally administered barium or iodized oil, in the mediastinum or in the adjacent pleural cavity. The iodized oil is easier to remove from the surgical field subsequently but the risk of iodism must be remembered.

The aspiration and examination of fluid from the pleural cavity may likewise confirm the diagnosis,[2, 26, 61, 67] as in Cases 3, 4, and 5. A fluid of sourish odor resembling vomitus offers conclusive proof. At times the odor of beer or other alcoholic beverage in the aspirated fluid may confirm its origin, as may the demonstration of food particles or acid, either free or combined. These are diagnostic only if one can be certain that the needle has not been introduced into

the mediastinal tissues and the soft tissues of the neck with a left hydropneumothorax. A diagnosis of ruptured esophagus or of a herniated stomach was made by one of us (R. W. M.) from the x-ray findings.

The patient was seen in surgical consultation at 10:30 P.M. on Nov. 28, 1944, at which time he was found in shock, was markedly cyanotic and dyspneic, and had a temperature of 102° F., and a pulse unobtainable at the wrist. There was subcutaneous emphysema of the tissues of the neck, and a left tension hydropneumothorax present with displacement of the heart and mediastinum to the right. A diagnosis of perforation of a hollow viscus into the left pleural cavity was made. A left pleural aspiration was carried out, and 700 c.c. of gas, and 900 c.c. of dark thin fluid without odor was aspirated. This accorded the patient rather marked relief from respiratory distress, but the shock continued. The aspirated fluid in the laboratory was found to be gastric contents with hydrochloric acid present. The hemoglobin at this time was 110 per cent, the hematocrit reading was 53 per cent red blood cells. The leucocyte count was 11,400 with 92 per cent polymorphonuclear leucocytes. The blood Rytz test was negative. Oxygen was administered.

Supportive treatment was given with adequate intravenous fluids, transfusions, and penicillin both intramuscularly and directly into the left pleural cavity, in an attempt to improve his condition sufficiently so that surgical exploration and closure of the esophageal rent could be carried out. Sodium sulfadiazine was also administered for twenty-four hours, but this was discontinued because of inadequate urinary output, which could not be increased in spite of adequate fluid intake. A transnasal gastric suction tube was inserted and continuous siphonage applied to keep the stomach empty; oral fluids were withheld. A left intercostal catheter thoracostomy was performed, and siphonage established for continuous removal of fluid from the left pleural cavity and to favor re-expansion of the lung. Additional fluid aspirated from the left pleural cavity showed a total acid of 55 degrees, without free hydrochloric acid, and cultures of this material revealed *Staphylococcus aureus.* In spite of supportive measures, chemotherapy, adequate drainage through the left pleural cavity, and repeated transfusions, the shocklike state persisted, and the urinary output remained extremely low (below 100 c.c. in twenty-four hours), the temperature mounted, and he died at 6:45 P.M. on Nov. 30, 1944, without ever improving sufficiently to permit surgical intervention.

Post-mortem examination by one of us (A. J. H.) was carried out at 9 A.M. on Dec. 1, 1944, fourteen hours after death, and revealed the following pertinent findings:

The peritoneal membranes were free and glistening. There were 50 c.c. of dark brownish fluid present. The liver weighed 1,600 Gm. and was of a yellowish-brown mottled appearance. The heart weighed 350 Gm., the coronary arteries were patent, but there was slight sclerosis present (grade 1 on the basis of 4) and with a few atheromatous plaques. The left pleural cavity contained about 800 c.c. of dark reddish-brown fluid and the pleural surfaces were covered with a yellowish exudate. The left lung was collapsed, hemorrhagic, weighed 650 Gm., and showed edema and atelectasis. The right pleural cavity contained 1,500 c.c. of dark reddish fluid; the right lung weighed 700 Gm., and was bluish-gray in color. There was decreased crepitation and complete atelectasis of all lobes.

The esophagus showed a linear perforation 3.5 by 1.2 cm. in the lower lateral portion just above the diaphragm, extending directly to the left pleural cavity. The point of perforation was covered with a large amount of bluish-gray material. The adjacent esophageal mucosa showed numerous small linear superficial erosions. The edge of the perforation was smooth and not indurated, and showed no gross evidence of carcinoma. The stomach contained some dark brown material, yet the walls appeared to be normal. There was obstruction at the pylorus which would admit only the tip of the small finger. There was a chronic duodenal ulcer 1 cm. in diameter on the anterior wall of the first part of the duodenum adjacent to the sphincter. On the posterior wall of the duodenum opposite the anterior ulcer were two small ulcers about ½ cm. in diameter. The kidneys weighed 110 and 150 Gm., respectively. The capsules stripped with difficulty, and there were a number of deep scars on the surface. The prostate was somewhat enlarged, grade 2, with one hemorrhagic area 1 cm. in diameter, but no evidence of malignancy.

along the left sternal border. Chest examination was reported as negative. There was general abdominal rigidity and tenderness, but no rebound tenderness. Neurologic examination revealed some cervical and back rigidity, and a general paresis more marked in the legs with some spasm in the quadriceps and gastrocnemius muscles. The general reflexes were negative except for absent abdominal and cremasteric reflexes. Superficial pain sensation was intact, but deep pain sensation was depressed.

The hemoglobin was 92 per cent, the leucocyte count 15,450 with 84 per cent polymorphonuclear leucocytes. The urine was negative, except that it was very concentrated. The spinal fluid was clear and colorless, but contained 107 cells per cubic millimeter, of which 20 per cent were neutrophiles, and 80 per cent mononuclear cells. The sugar content was 85 mg. per cent, and the protein 37 mg. per cent.

A clinical diagnosis of acute anterior poliomyelitis was made. Chest and body packs were ordered, and oxygen was given for dyspnea as the respiratory distress increased. The clinical course was increasingly downhill, and respiratory distress increased to the point where a respirator was necessary. He gradually lapsed into coma and died at 4:15 P.M. on Oct. 25, 1943. At no time were there any clinical findings to suggest esophageal perforation, although this patient was desperately ill, irrational, and later comatose. The difficulty in breathing was considered to be on the basis of poliomyelitis. No subcutaneous emphysema was noted at any time.

Post-mortem examination 2¼ hours after death revealed a slitlike perforation in the middle third of the esophagus, opening directly into the left pleural cavity. The left pleural cavity contained 500 c.c. of gastric contents containing blood. There were no adhesions present. The left lung weighed 200 Gm., and was grossly negative. The right lung and pleural cavity were negative. In the fundus of the stomach, the mucous membrane was definitely eroded, and there were several large areas of superficial ulceration about 4 by 4 cm. in diameter covered with a gelatinous mucoid coating. Microscopically the stomach showed only a post-mortem degeneration, with no pre-mortem disease. The esophagus upon microscopic section showed epithelial ulceration, with subepithelial neutrophilic infiltration. There were definite post-mortem changes present. There was no inflammatory reaction in the external layers of the esophagus. An acute superficial esophagitis was present. Microscopic sections of the brain revealed areas of perivascular neutrophilic and mononuclear infiltration, with multiple miliary foci in the gray area. Final diagnosis was acute poliomyelitis, acute superficial esophagitis. It was the pathologist's opinion at the time of the autopsy that the perforation was a post-mortem lesion, but the evidence at hand does not fully confirm his. The post-mortem examination was conducted 2¼ hours after death. The perforation was slitlike, in the middle third of the esophagus, and the pleural cavity contained gastric contents and blood. These are not the findings of the typical post-mortem digestion perforation.

CASE 3.—W. G., a 70-year-old man, was admitted to St. Barnabas Hospital at 8:15 P.M., on Nov. 27, 1944, and presented the following history: General health apparently had been quite good until March of 1943 when he developed symptoms suggestive of duodenal ulcer, and had been placed on medical management with benefit. He was then apparently relatively symptom-free until Nov. 13, 1944, when he developed nausea, vomiting, and loss of appetite. He returned to the ulcer regimen, the symptoms subsided, and though rest was advised, he insisted upon going back to work. Two weeks later on Nov. 27, 1944, at 6 P.M. he developed a sudden severe attack of abdominal pain, mostly in the epigastric region, with difficulty in breathing, and became so ill that he was removed to the hospital by ambulance, arriving two hours after the onset of the attack.

Upon admission, temperature was 98.6°F., pulse 132, respiration 40, blood pressure 90 over 50 mm. of mercury. He was complaining of very severe epigastric pain, was definitely in shock, with profuse perspiration, and was evidently critically ill. There was definite epigastric tenderness without rigidity and dullness to percussion in the left lower part of the chest. X-ray films of the abdomen with the patient in an erect position showed no free gas under the diaphragm. X-ray films of the chest revealed emphysema of

By the next day his general condition had deteriorated considerably. He was very weak and cyanotic, his blood pressure had dropped to 80 over 65 mm. of mercury, and there was increased dyspnea. A left thoracentesis was performed and 1,870 c.c. of thin brownish fluid without foul odor were removed. Examination of this fluid showed 217,000 cells per cubic millimeter, of which 93 per cent were polymorphonuclear leucocytes, and 78,000 red blood cells. Cultures of the fluid revealed a pneumococcus type IV. Sulfadiazine and penicillin were instilled into the pleural cavity following the aspiration. Abdominal paracentesis revealed only an occasional polymorphonuclear leucocyte but no bacteria present. Following the aspiration and intravenous administration of fluids and blood, the condition improved slightly and color became better under oxygen therapy. On February 5, an additional left thoracentesis was performed, and 1,000 c.c. of brownish fluid were aspirated.

The patient was seen in surgical consultation on Feb. 6, 1945, and an intercostal catheter thoracostomy was carried out to relieve the increasing left tension hydropneumothorax. *Perforation of the esophagus into the left pleural cavity* was recognized at that time (T. J. K.), but it was quite evident that the patient was in no condition for any major surgical therapy. The fluid removed from the chest showed a pH of 5.5 and was negative for fats, urobilin, and urobilinogen. The hemoglobin upon admission was 83 per cent, the leucocyte count was 18,300, with 81 per cent polymorphonuclear leucocytes. Electrocardiographic studies showed a sinus tachycardia, an apparent left axis deviation, and marked low voltage on all leads which was interpreted as indicative of severe myocardial damage.

The *diagnosis of perforation of the esophagus into the left pleural cavity* was readily confirmed by administering a small amount of grape juice by mouth, and promptly recovering the same material in the fluid removed by catheter from the left pleural cavity. The clinical course was slowly and progressively downhill from the onset. The temperature varied from 100 to 104° F. per rectum, and on Feb. 15, 1945, the patient and his family, realizing fully the gravity of the situation, decided to move him to Rochester to the Mayo Clinic where he died within two hours of arrival.

*Post-mortem examination performed there** revealed a clean, slitlike perforation of the lower esophagus, directly to the left pleural cavity, with little associated mediastinitis. There was no gross evidence of previous esophageal ulceration. There was also a locally perforating duodenal ulcer with hemorrhage, and a very localized associated peritonitis. Although a diagnosis of perforation of the esophagus of the left pleural cavity was made early in this patient, at no time could surgical intervention be seriously considered because of age, senility, desperate physical condition, and the apparent duration of the process before admission. Survival was unusually long for a patient presenting this serious condition, and probably was due primarily to the fact that the perforation occurred directly to the left pleural cavity with little mediastinal infection and to a lesser degree to adequate pleural drainage. From the standpoint of the local findings alone, surgical repair would have been quite simple.

CASE 5.—W. F. C., a white man, aged 67 years, was admitted to the Minneapolis General Hospital at 4:40 P.M. on Feb. 19, 1946, in shock with marked dyspnea and extensive subcutaneous emphysema of the chest and neck. The following history was obtained: Shortly after noon of the same day while walking down the street on the way to lunch, he suddenly developed very severe epigastric pain, pain in the left side of the chest, and immediately collapsed. There was no vomiting. He was taken to his home by taxicab where his family reported that he soon developed marked difficulty in breathing and increased swelling of the neck and face. A local physician was called, who tentatively diagnosed the condition as heart block and gave an intravenous injection which relieved the pain somewhat. The pain, dyspnea, and swelling gradually increased until the patient was brought to the hospital one or two hours later.

Past history was negative except for a right parietal skull fracture in 1941. His wife reported that he had some gas and difficulty with meals for a couple of years, occurring every week or so, but that he obtained definite soda relief. An x-ray study of the gastrointestinal tract a few months before, however, had been reported as negative. There had been no

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*Reported through the courtesy of Dr. H. J. Moersch.

Microscopically, kidneys showed no findings to account for the oliguria. Microscopic sections of the esophagus in the region of the perforation showed an acute ulceration, with suggestion of superficial erosion of the epithelium. The borders were covered with acute fibrinous exudate. The entire esophageal wall in the region of the perforation showed the microscopic picture of an acute inflammatory exudate. There was no malignancy present, and no areas of ectopic gastric mucosa.

COMMENT

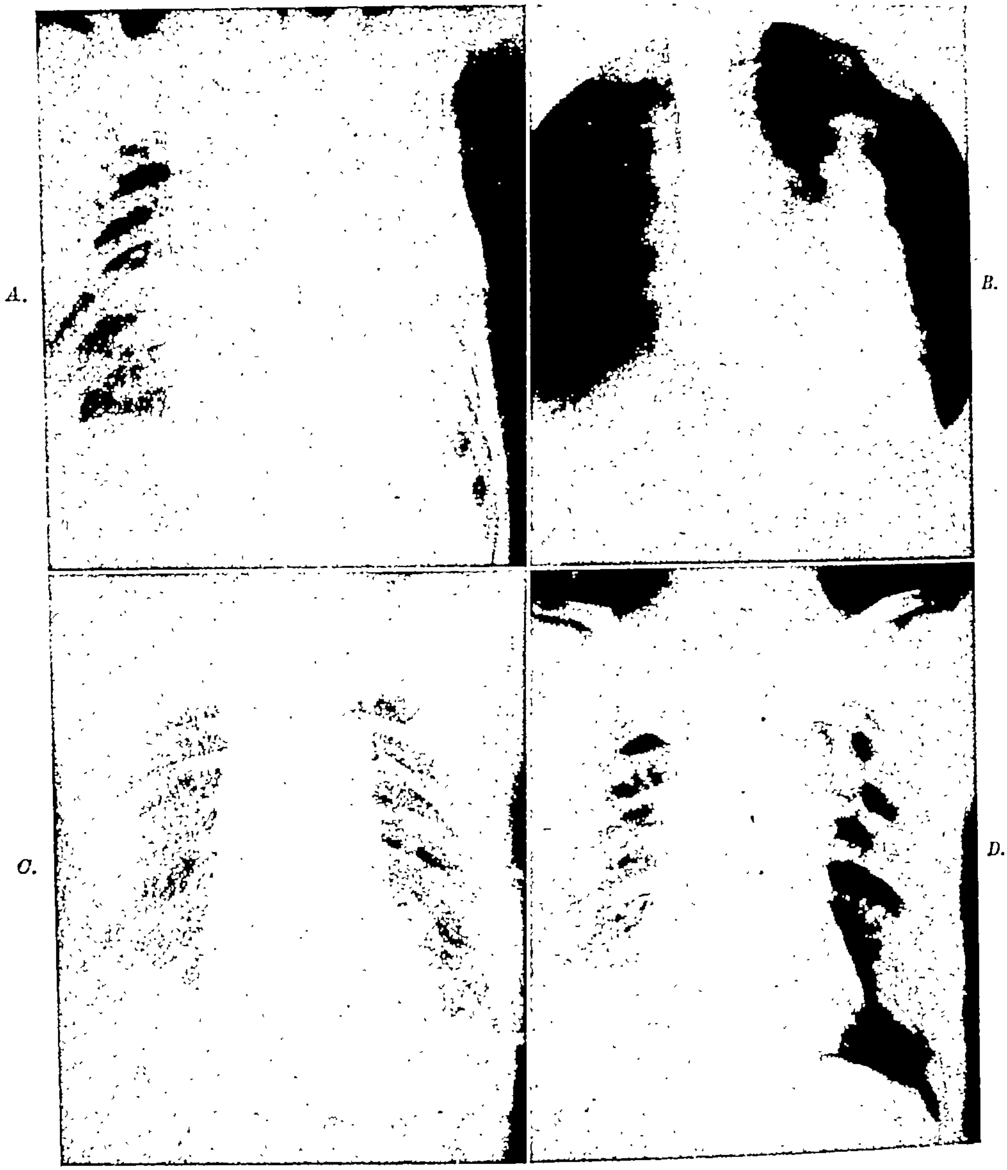
This patient's oliguria was undoubtedly related to the persistently low blood pressure. In light of our present knowledge and experience, he should have been operated upon without delay. The falacy of postponing surgical exploration until the condition could be improved is well emphasized by the final result.

CASE 4.—A. A., a 74-year-old man, was admitted to Minneapolis General Hospital on Feb. 3, 1945, complaining of severe epigastric pain, vomiting of blood, inability to swallow solid foods, and a fifty pound weight loss. He gave a history of epigastric distress coming two to three hours after meals for the past ten years, and had been studied at the Mayo Clinic some five years before, where diagnosis of chronic duodenal ulcer was made, and appropriate medical measures recommended. He was seen again at the Mayo Clinic in April, 1943, where again a chronic duodenal ulcer with a large crater and some evidence of obstruction was found. He was hospitalized and the ulcer treated medically with satisfactory improvement.

He returned again to the Clinic in July, 1944, with symptoms similar to those previously described, plus the complaint of a great deal of pain in the left lower portion of the chest, aggravated upon deep breathing and by motion of the left arm. Findings with x-ray views of the chest were negative at that time except for some elevation of the left diaphragm and some tortuosity of the aorta. An x-ray of the stomach and duodenum at that time revealed a duodenal ulcer with a small crater. Because of the pain in the lower part of the chest and some history of dysphagia an esophagoscopic examination was performed, but nothing abnormal was found. On an ulcer diet, he was relieved of the symptoms. In December, 1944, he again returned to the Mayo Clinic because of some difficulty in swallowing, but it was the impression that at that time the symptoms were functional in nature. Esophageal sounds up to No. 41 French were passed without encountering any evidence of obstruction.

On Jan. 20, 1945, two weeks before admission to the Minneapolis General Hospital, he had been vomiting considerably during the day, a dark coffee-ground material containing some fresh blood. That evening while lying in bed, he was seized with a sudden very severe epigastric pain which doubled him up. After a time the pain lessened somewhat, but persisted in a moderately severe form until admission to the hospital, where he frequently vomited coffee-ground material containing some bright blood and passed black tarry stools. He had been vomiting four or five times daily for the two weeks prior to admission, was very weak and lethargic, and complained considerably of shortness of breath. There was an indefinite history of dysphagia for solid foods for several months, a history of some dyspnea on exertion for two or three years, with occasionally swelling of the lower extremities.

Physical examination upon admission, Feb. 3, 1945, revealed a somewhat senile man, very ill, with evidence of recent extensive weight loss. The pulse was 120 and of poor quality, blood pressure was 100 over 64 mm. of mercury, and rectal temperature was 101° F. He was very pale and lethargic. There was no emphysema of the neck or chest. Examination of the heart and lungs was reported as negative. There was moderate abdominal rigidity of the upper half of the abdomen, but no pain or tenderness, and but slight rebound tenderness in the upper abdominal region. A tentative diagnosis of chronic peptic ulcer with hemorrhage was made but the possibilities of carcinoma of the stomach and perforated peptic ulcer were considered. A bedside roentgenogram of the chest, not in erect position, showed an increased density in the left lower part of the chest suggestive of fluid without a fluid level and a localized accumulation of gas in this region.



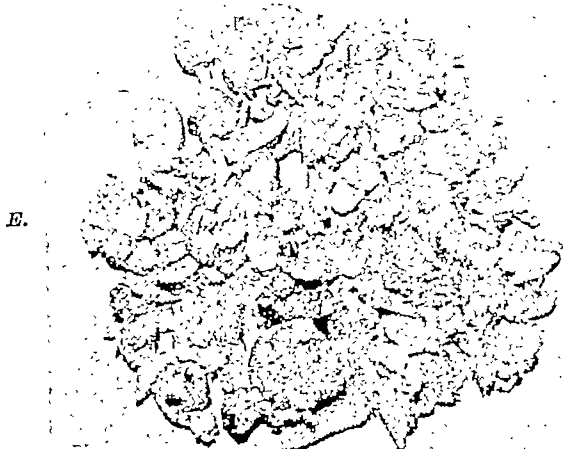


Fig. 3 (Case 5, W. C.).—*A*, Admission chest film (not in erect position), left tension pneumothorax mediastinal and cervical emphysema. *B*, Barium in esophagus and left pleural cavity. *C*, Postoperative chest film, suction catheters in position, lung expanded. *D*, Postoperative chest film, eight days, catheter removed. *E*, Small portion of undigested food (twenty hours after ingestion) removed from left pleural cavity at operation.

previous food dyscrasia or dysphagia. He had been in the habit of using mineral oil and laxatives for some time. There was slight nocturia one to two times per night for five to six years. There had been an indefinite history of some pleurisy-like pain in the left side off and on for some time.

Upon admission, he was suffering from marked respiratory distress, and was rational but could talk very little because of dyspnea. The skin was warm and dry, and there was marked subcutaneous emphysema of the neck, left side of the chest, and axilla. The trachea was deviated to the right. The neck veins were not distended. Blood pressure was 80/42, the pulse 140, regular but fast, and very weak. The respiratory rate was 40 per minute. Chest examination showed the right lung clear. The left side of the chest was hyperresonant throughout, with an absence of breath sounds. The heart sounds were faint, rapid, and regular. The abdomen showed no tenderness, rigidity, or masses. The diagnosis upon admission was spontaneous pneumothorax on the left, cause undetermined. X-ray view of the chest revealed a left hydropneumothorax with subcutaneous emphysema, more marked on the left side.

The diagnosis of spontaneous perforation of the esophagus was made by one of us (T. J. K.) during telephone conversation with a surgical resident at this time, with a recommendation for surgical repair made as soon as the patient could adequately be treated for shock and prepared for surgery. A small amount of barium given by mouth appeared promptly in the left pleural cavity on x-ray films. Intravenous fluids, penicillin, sodium sulfadiazine, and blood were administered to the patient in preparation for surgery. The hemoglobin was 95 per cent, the leucocyte count 7,000 per cubic millimeter, with 98 per cent polymorphonuclear leucocytes, and only 2 per cent lymphocytes. The urine showed specific gravity of 1.033, albumin 3 plus, a faint trace of sugar, and 3 to 4 red blood cells, and 4 to 6 leucocytes per high-power field in the sediment. Fluid aspirated from the thoracic cavity was of an odor suggestive of stomach contents, showed yeast and gram-positive cocci in chains on smear, and a nonhemolytic streptococcus on culture. Electrocardiographic studies revealed a sinus tachycardia with elevation of the ST in Leads II and III suggesting myocardial damage.

Surgical exploration was carried out at 10:30 P.M., approximately 8½ hours after the onset of the trouble, under intratracheal cyclopropane anesthesia, after the insertion of a nasal suction tube into the esophagus and the stomach. The chest was opened through a posterolateral incision with resection of a wide segment of the ninth posterior rib. Upon opening the pleural cavity, more than 1 liter of fluid and food was encountered with numerous peas, beans, pickles, and other undigested food remnants easily recognizable. This represented food taken twenty hours prior to the onset of the sudden attack. All solid food material was removed from the pleural cavity, which was then thoroughly irrigated with a large amount of sterile water until all foreign material had been removed. The barium which had previously been given by mouth could be observed as a thin white coating on the pleura. This was removed as thoroughly as possible. Exploration revealed a 9 cm. rent in the left pleura overlying the esophagus, and a 4 cm. long perforation on the left posterolateral wall of the esophagus just above the cardiac end of the stomach. The mucosa of the esophagus was protruding through this rent. Direct examination revealed no evidence of chronic ulceration or neoplasm in this area. A finger inserted into the esophageal perforation immediately entered the stomach, and through this opening all contents of the stomach were removed. There was no evidence of scarring or ulceration in the stomach that could be demonstrated through this exposure.

The rent in the esophagus was then closed with interrupted sutures of 000 silk, first to the mucosa, a second layer through the overlying muscle, and a third layer through the overlying pleura, leaving, however, a small communication between the mediastinum and the left pleural cavity for drainage. The lung was expanded repeatedly during the procedure. Four intercostal catheters inserted through stab wounds were left in the pleural cavity. Five grams each of sulfanilamide and sulfathiazole were then sprinkled into the mediastinum and pleural cavity, and 100,000 units of penicillin injected. The chest wall was then closed without further drainage. The patient tolerated the surgical exploration extremely well, though the blood pressure when the anesthetic was administered was only 60/40, and at the end of surgical procedure it had come up to 100 over 60 mm. of mercury.

Post-mortem examination revealed that the immediate cause of death was pulmonary embolism. The main branch to the right pulmonary artery was obstructed by a large antemortem clot, the right lung also containing two small fresh hemorrhagic infarcts, showing that he had had minor embolic episodes prior to the terminal embolus. The source of the embolus was not demonstrated; the leg, veins, and pelvic veins were free of blood clots. The left lung showed partial atelectasis and also a small infarct. The left pleural cavity showed a suppurative pleuritis, but contained little fluid. There were still a few food particles clinging to the surface of the left lung. The esophagus showed a linear area of ulceration on the posterolateral aspect of the wall just above the cardia. This tear measured 4 cm. in length. The outer surface was partially closed by sutures which had partially broken down. There was very little evidence of healing. The surrounding mucosa of the esophagus showed evidence of acute esophagitis with no evidence of any acute or chronic ulcers in the stomach or duodenum. Microscopic examination of the esophagus showed the wall to be necrotic and infiltrated with large numbers of neutrophiles, but with no evidence of malignancy. It is unfortunate that this man died of a pulmonary embolism or that the preliminary signal emboli were not recognized and venous ligation carried out, for with the postoperative course progressing satisfactorily we have every reason to believe that he would have recovered from this serious illness.

Spontaneous perforation of the lower esophagus into the mediastinum or pleural cavity is always a tragic occurrence. It presents a clinical picture so characteristic that the diagnosis should be made in the majority of instances if the possibility of such a condition is considered. While it may be produced by mechanical factors alone, the importance of a local esophagitis weakening the esophageal wall must be recognized. To date the correct diagnosis has been made during life fourteen times[4, 5, 7, 14, 16, 21, 23, 46, 50, 73, 74] including Cases 3, 4, and 5 in the present series. From this group operative repair has been carried out five times, four transpleural[5, 14, 16] with our Case 5 and one transabdominal,[23] with recovery in two patients.[5, 16] Early diagnosis, prompt surgical repair, and proper postoperative treatment may be expected to save a considerable number of these patients from an otherwise certain fatal termination.

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Postoperatively the patient was kept in an oxygen tent, and penicillin and sulfadiazine were administered in adequate dosage. Intravenous fluids and blood were administered as indicated. Continuous suction was maintained on the intercostal catheters and a considerable volume of thin serous fluid obtained daily. The lung remained expanded well, and little or no fluid was allowed to collect in the pleural cavity. The postoperative course was somewhat stormy with elevated temperature, and though the blood pressure remained well above 100 most of the time, he had several sinking spells of short duration, the cause of which could not be determined. Continuous nasal suction was maintained for the first six days, following which small amounts of fluid were injected directly through the tube into the stomach.

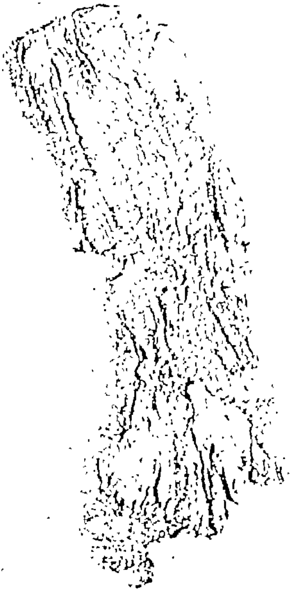

Fig. 4 (Case 3, W. C.).—Post-mortem specimen; spontaneous rupture of lower esophagus on ninth postoperative day.

A roentgenogram of the chest on February 24, five days postoperatively, revealed the lung fully expanded with no change to the parenchyma of the lung. The general condition improved and everyone was certain that the patient was going to recover. On Feb. 26, 1946, he was alert and cooperative, and apparently had few complaints. X-ray view of the chest on this day, however, showed an area of mottled increased density in the peripheral portion of the right lung field, which was interpreted as a patch of pneumonia. He continued to improve until February 27, eight days postoperatively, when he suddenly complained of severe pain in the right side of the chest, and for a time was irrational. Blood pressure dropped, but after a short time came up again, and apparently he was all right. There was no expectoration of blood, no edema, tenderness, or other findings to suggest a process in the lower extremities. Toward midnight he had another attack of pain in the chest and rapidly went downhill, dying at 6:40 A.M. on Feb. 28, 1946, on the ninth postoperative day.

SPONTANEOUS RUPTURE OF THE ESOPHAGUS

Report of One Case, With Recovery

Julian A. Moore, M.D., Asheville, N. C., and
James D. Murphy, M.D., Oteen, N. C.

SPONTANEOUS rupture of the esophagus is a very unusual occurrence. In August, 1946, Eliason and Welty* reviewed forty-one recorded cases of rupture (not perforation) of the esophagus, and added case histories of three of their own patients. They stated that no cases had been reported in the literature in which recovery had taken place, although in an editorial footnote in the 1944 *Year Book of Surgery,* Graham mentioned two cases which resulted in empyema with recovery following drainage.

Since the condition of spontaneous rupture of the esophagus is so rare, recovery so unusual, and the surgical management so complicated, it is hoped that this presentation of a case with recovery will be helpful to one confronted with the same problem.

CASE REPORT

R. E. W., a 33-year-old veteran of World War II, was admitted to the Veterans Administration Hospital, Oteen, N. C., on June 2, 1946, at 11 P.M. and gave the following history:

From 1937 to 1939, the patient complained of irregular attacks of "acid indigestion" and was treated for a supposed peptic ulcer. No radiographic studies were made. From 1939 to 1944 he had occasional upper abdominal discomfort which was relieved by sodium bicarbonate. On one occasion in 1941, he complained of sudden, severe pain in the upper abdomen. He became acutely ill, was hospitalized, operated upon, and recovered. He was told by his surgeon that he had acute pancreatitis. After this episode he felt well with an occasional dose of soda and without dietary restrictions until May, 1946. He served as a master sergeant in an engineers' battalion from May, 1943, to March, 1946. Twelve months of this service were spent in the tropics and during the entire thirty-four months he was not hospitalized.

On May 18, 1946, the patient consumed five highballs from 5 to 10 P.M., but was not intoxicated and did not vomit. He went to bed at 11 P.M. and arose at 8 A.M. He ate breakfast consisting of fruit juice, cereal, eggs, toast, and coffee. He then walked three-fourths of a mile to buy a paper and felt perfectly well. While at the paper stand, however, he was seized with a sudden, severe pain in the left epigastrium, which "doubled him up." He immediately vomited bloody material. He rode home in a cab and vomited three times on the way, the vomitus being described as bloody. The pain and nausea persisted and he was admitted to a hospital in his own community about noon on May 19, 1946.

The surgeon's notes stated that the patient, in obvious pain, was lying in bed with both knees flexed. Physical examination revealed boardlike rigidity of the left rectus muscle and marked rigidity of the right rectus muscle with tenderness across the entire upper abdomen.

From the Department of Surgery, U. S. Veterans Hospital, Oteen, N. C.

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Read (by title) at the Twenty-Seventh Annual Meeting of the American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

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On June 2, 1946, he was seen by one of us (J. A. M.) in consultation. A thoracentesis by this consultant in the left ninth interspace near the spine yielded several ounces of a brownish, purulent, sour-smelling fluid with acid reaction. It was very suggestive of gastric contents. The next procedure was to give barium by mouth. Under the fluoroscope this was seen to pass rapidly into the stomach. Then a roentgenogram was made with the patient in the upright position; in this film the stomach appeared normal. Next, a film made (Fig. 3) with the patient in the head-down position showed the stomach to be in the left part of the chest. A tentative diagnosis of a diaphragmatic hernia with a perforated ulcer in the herniated portion of the stomach was made.

Fig. 2.—Portable roentgenogram made on May 25, 1946, shows a pneumothorax with some fluid and a wide mediastinum.

The patient was transferred to the Veterans Administration Hospital at Oteen, N. C. On June 3, 1946, the red blood cell count was 3,340,000, hemoglobin 9 Gm., and the leucocyte count was 10,900 with 80 per cent neutrophiles. The sedimentation rate was 31 mm. per hour. The urine showed a trace of albumin with an occasional white and red blood cell and a few cylindrical casts. The blood pressure was 125/60. Moist râles were present over the left upper lobe and there were diminished breath sounds at the base. X-ray examination showed the left lung to be partially collapsed with a broad adhesion between the first and second ribs. There was a collection of air medially and laterally in the upper third of the pleural cavity and of fluid and air just above the diaphragm. There was a streak of barium above the left border of the heart outside of the gastrointestinal tract.

On the assumption that the patient had empyema as a result of a perforation in the herniated portion of the stomach, a left thoracotomy was done at the level of the ninth rib in the posterior axillary line, under local anesthesia. After resection of 4 cm. of the rib, a large drainage tube was inserted and fixed in place with a safety pin and adhesive dressing.

Culture of the fluid removed at operation showed *Staphylococcus areus*, nonhemolytic streptococci, and a yeast form identified as Monila. No acid-fast bacilli were found.

The leucocyte count on admission was 6,400, but rose in a few hours to 9,100. The temperature was 99° F., pulse rate 100, and respirations 20 per minute. On admission a roentgenogram (Fig. 1) was made and was interpreted as negative. A tentative diagnosis of perforated peptic ulcer was made and a laparotomy was performed at 5:30 P.M., about 5 hours after admission. No perforation was found and a careful search of the peritoneal cavity revealed no pathology to account for the symptoms. The omental tissue had a peculiar appearance and a piece was removed for examination before the abdominal cavity was closed. The pathologist's report was fibrosis of the omentum, probably due to an old pancreatitis.

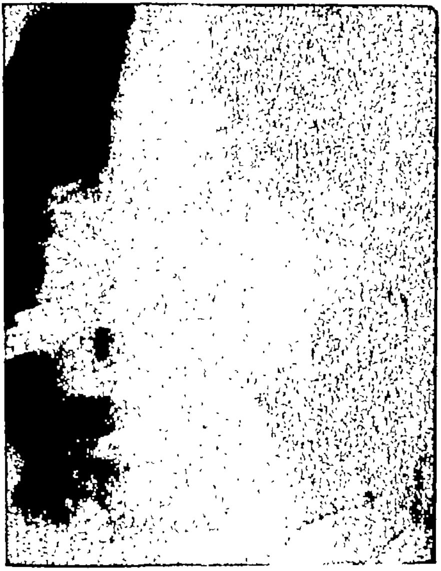

Fig. 1.—Roentgenogram made before operation on May 19, 1946. Note area of lessened density behind the heart. In the light of the subsequent history we feel that this shadow may be characteristic of the condition described.

The postoperative period was stormy. The temperature rose to 103.4° F.; the pulse rate increased to 120, and respirations to 34 per minute shortly after operation. The next day, May 20, crepitant râles were heard and later that day a friction rub was noted over the left lower lobe. On May 21, the left lower part of the chest was tympanitic and there was some dyspnea. On May 25, a roentgenogram of the chest (Fig 2) was made, which showed a wide mediastinum and a left hydropneumothorax. Thoracentesis yielded 135 c.c. of clear, amber fluid which was negative on smear for organisms. The cells in the fluid were predominantly lymphocytic. On May 28, the thoracentesis was repeated and 240 c.c. of air withdrawn. No fluid was obtained, but the procedure relieved the dyspnea. During the next four days several thoracenteses were performed, but only small amounts of fluid and air could be obtained.

During this period, the temperature was septic and ranged from 101 to 106° F.; the pulse rate varied from 90 to 120; and the respirations from 24 to 40 per minute. He was given 1,940,000 units of penicillin intramuscularly from May 20 to June 2. He took some liquids by mouth and was given glucose in saline solution intravenously almost daily.

The left lung was found adherent to the diaphragm and to the lateral chest wall. There was an anterior empyema space and a posterior space which communicated with the fistula. The lung was separated from the diaphragm with difficulty but without injury. After the lower lobe of the lung had been completely freed, a large aperture was palpated in the diaphragm at the site of the esophageal hiatus. This appeared to be large enough to permit a hernia, but the stomach was not present in the thoracic cavity.

The left diaphragm was then incised, the abdominal cavity entered, and the stomach identified. The incision in the diaphragm was extended to the hiatus and the esophagus visualized. A rent 4 cm. long was found in the anterolateral portion of the esophagus just above the diaphragm. This was unquestionably an old tear, because the mucous membrane was everted and healed to the muscular coat. The mucous membrane itself appeared perfectly normal. The tear extended to the cardia. At the upper end of the tear the esophagus was fibrous and adherent to the aorta at that point. No satisfactory explanation for this lesion could be arrived at. The lower end of the esophagus was separated from the aorta and was completely mobilized.

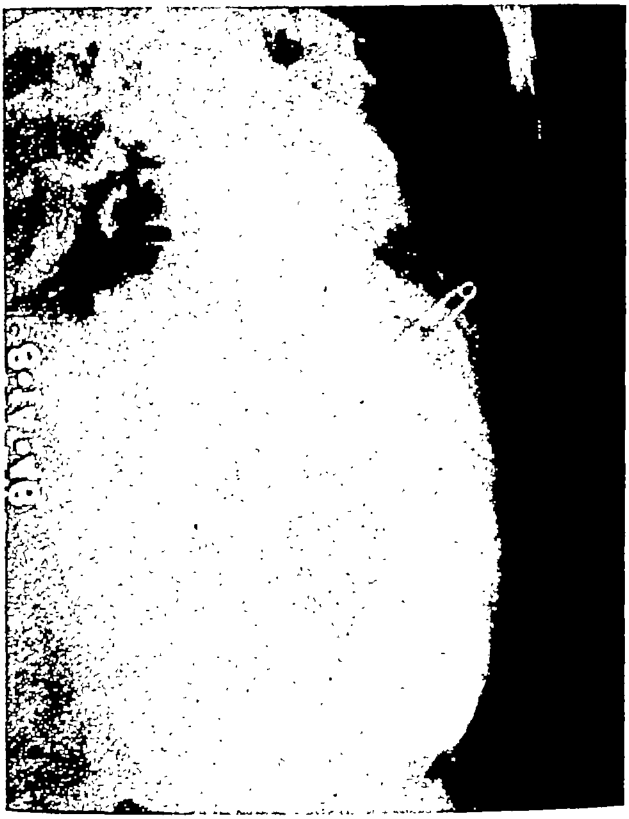

Fig. 4.—Roentgenogram made on Aug. 2, 1946, in the head-down position after ingestion of barium shows the stomach to be in the abdomen.

An incision about 4 cm. long was made through the cardia and into the fundus of the stomach. An esophagogastroplasty was then done approximating the edge of the esophagus to the cut surfaces of the stomach with interrupted Connell sutures of silk. This was reinforced with a continuous silk suture. The incision in the diaphragm was closed with interrupted mattres sutures of silk down to the hiatus. The fundus of the stomach was sutured to the diaphragm to remove tension from the line of repair. A large rubber tube for drainage was inserted at the site of the original thoracotomy and the wound was closed in layers around it.

Convalescence was remarkably smooth. Feeding was continued through the jejunostomy tube until the tenth postoperative day, at which time the tube was removed. No leakage

Penicillin was given at the rate of 20,000 units every three hours. A Levine tube was passed intranasally into the stomach and suction applied. Part of the water or milk given by mouth escaped through the thoracotomy drainage tube. A tablet of methylene blue was given orally and the blue dye appeared in a short time in the drainage through the thoracotomy tube. Nutrition was maintained by the intravenous administration of glucose in saline and amigen solution.

On June 6, 1946, under spinal anesthesia, a jejunostomy by the Wangensteen technique with a 14 French catheter was done by one of us (J. A. M.). After this, the patient was given nothing by mouth and was fed approximately 3,000 calories a day, supplemented by vitamins A, B, D, and ascorbic acid through the jejunostomy tube. This was supplemented by several intravenous infusions of glucose in saline and amigen and by four blood transfusions of 500 c.c. each of citrated blood between June 6 and June 28. The thoracic cavity was irrigated four times daily with a 1 per cent sodium bicarbonate solution.

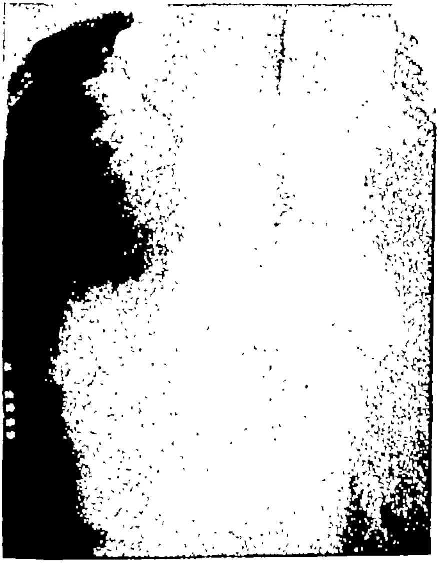

Fig. 3.—Roentgenogram made June 2, 1946, in the head-down position after ingestion of barium sulfate. This was interpreted as being a diaphragmatic hernia.

During the first few days, there was a reversal of the albumin-globulin ratio, but the total protein, nonprotein nitrogen, chlorides, and blood calcium remained within normal limits. The temperature in the meantime had gradually subsided and the drainage from the left side of the chest gradually ceased.

By June 28, twenty-two days after jejunostomy, the patient's condition had so improved that we felt he could undergo the major procedure of repair of the supposed diaphragmatic hernia. Under intratracheal anesthesia of nitrous oxide, oxygen, and ether, supplemented with Pentothal sodium during induction, the operation was undertaken by both of us (J. A. M. and J. D. M.). The incision was made over the left ninth rib with resection of the ninth rib anterior and posterior to the thoracotomy wound. The eighth rib was next divided behind the angle. The pleura was incised in the bed of the ninth rib and a rib spreader inserted.

occurred. Liquids by mouth were started in small amounts on the seventh postoperative day, and on the fourteenth day a high caloric, bland diet was given. A regular diet was instituted on August 12 and the patient has experienced no difficulty in swallowing at any time.

Following the latter operation, the expected rise in temperature was moderate and of short duration and it has been entirely normal since July 23. The drainage from the pleural cavity gradually decreased as the left lung re-expanded. The drainage tube was removed on Sept. 21, 1946. The wound has completely healed. Penicillin was continued until August 1, a total dosage of 9,120,000 units having been given. The patient was allowed out of bed on Aug. 2, 1946, and was gradually allowed to increase activities. The stomach is in the abdomen (Fig. 4), as shown by the roentgenogram taken in the head-down position. The lung was completely re-expanded (Fig. 5) and the esophagus appeared normal (Fig. 6). He was discharged on Oct. 24, 1946, completely recovered.

COMMENT

In their discussion of the subject of rupture of the esophagus, Eliason and Welty stated: "The mortality rate reported so far in spontaneous rupture of the esophagus is 100 per cent, excluding the two cases mentioned by Graham. Most patients succumb within twenty-four hours, though one patient survived seventeen days. With improved techniques in anesthesia, freer use of blood and plasma for intravenous infusion, and effective chemotherapeutic agents, the limiting factor in the treatment of this condition is that of diagnosis. It does not seem at all unlikely that soon recoveries from this condition will be reported."

Spontaneous rupture of the esophagus should be considered in the differential diagnosis in any patient who suffers severe, upper abdominal pain associated with vomiting, particularly of blood. If this syndrome is accompanied by cervical emphysema or the development of a pneumothorax, the lesion should be strongly suspected. We think that when a pocket of gas is discovered behind the heart, as shown in Fig. 1, we would immediately make the diagnosis. Two other procedures should be carried out to confirm the diagnosis: first, the administration of barium with subsequent roentgen films. The presence of barium in the chest would confirm the diagnosis. Second, if on thoracentesis, gastric contents were aspirated, this would indicate either a rupture of the esophagus or a perforation of the herniated stomach.

As soon as the diagnosis is made, drainage of the thoracic cavity should be instituted. No food or drink should be given by mouth and a jejunostomy should be done in order to feed the patient. Antibiotic agents should be given in adequate doses. Nutrition must be maintained. Glucose and amino acids, blood or plasma transfusions are indicated to supplement jejunal feedings. We believe that with early recognition of the condition and prompt application of the measures outlined here, many of these patients can be saved. In all probability, the rupture would heal spontaneously and if it did not, repair could be successfully effected at a later date. We question the wisdom of immediate repair of the ruptured esophagus in those patients whose desperate condition following the accident is a strong contraindication to any major surgical procedure.

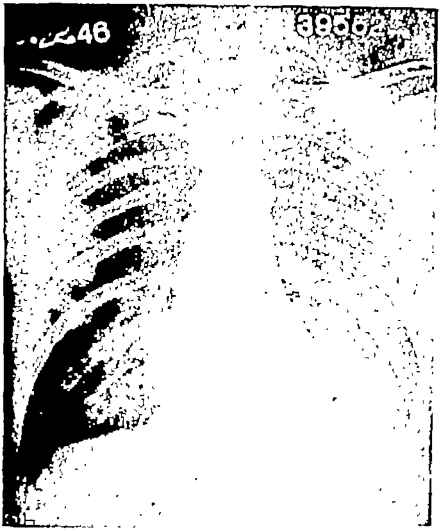

Fig. 5.—Roentgenogram made Oct. 22, 1916, showing lung to be completely re-expanded.

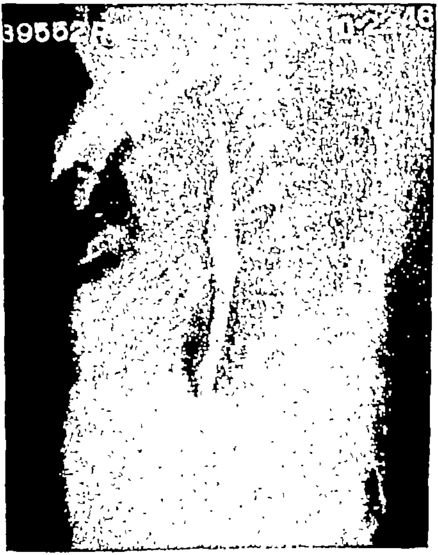

Fig. 6.—Roentgenogram after ingestion of barium sulfate, showing esophagus to be normal.

repair and excision of such fistulas are indicated. Such pseudodiverticula and fistulas (Fig. 1) when associated with carcinoma definitely indicate its inoperability.

The rare case of esophagotracheal fistula resulting from a traumatic or inflammatory process can be cured by operation and this must be accomplished to save the patient's life. A transpleural posterolateral approach, ligating and sectioning the azygos major vein with excellent mobilization and visualization of the membranous portion of the trachea and esophagus as well as the fistulous tract (Fig. 2) will permit a meticulous excision of the fistula or closure of the trachea and esophagus and, if massive doses of penicillin and streptomycin are used, primary healing without residual infection can be expected.

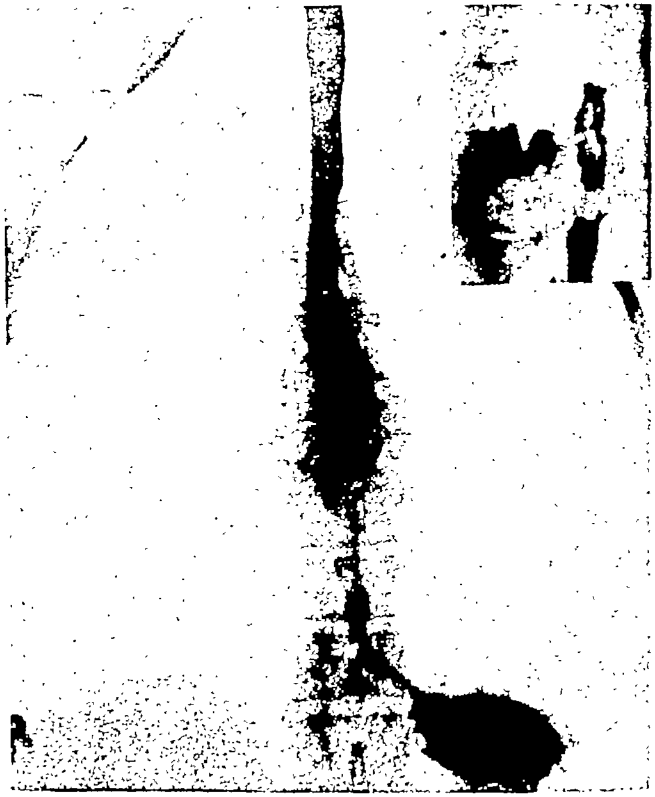

Fig. 1.

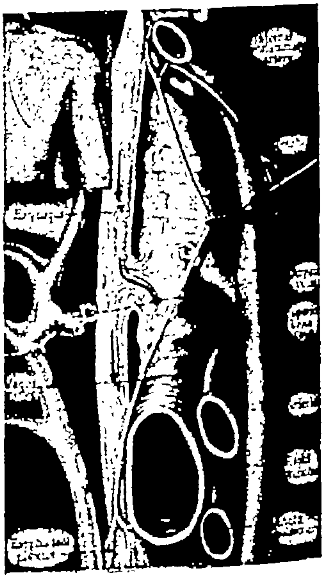

Fig. 2.

Fig. 1.—Barium study of esophagus, showing perforation of a carcinoma of the esophagus into the mediastinum and right lung, producing a pseudodiverticulum.

Fig. 2.—Operative sketch showing the exposure obtained through the right thorax of the esophagotracheal region for repair of esophagotracheal fistula.

The pulsion type of thoracic diverticula, however, is similar clinically to those so frequently seen in the esophagopharyngeal region. These diverticula produce symptoms and nutritional decline of the patient owing to the dependent position of the sac which fills with liquid and food and gradually becomes large enough to produce mechanical angulation and obstruction of the esophagus. When the diverticulum reaches this stage of obstruction, it seriously jeopardizes the patient's health and life, and only surgical treatment can be expected to give him relief of these serious symptoms. Although a

DIVERTICULA OF THE THORACIC ESOPHAGUS

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SINCE Zenker's classification, in 1877, of esophageal diverticula into pulsion and traction types, many individual case reports and a few larger series of diverticula of the thoracic esophagus have been reported. A much larger series of diverticula of the pulsion type in the pharyngocervical esophagus has been reported, and the surgical management, technical aspects, and the treatment of these cases have become well established. In addition, these reports have described fully the pathologic and clinical aspects of these two now well-accepted and well-established types. Diverticula of the thoracic portion of the esophagus, however, are far less common and very little has been written regarding their specific surgical management. I wish, therefore, to present a small series of diverticula of the thoracic esophagus in which the patients required surgical relief of their symptoms, and to describe in more detail their surgical management and the technical aspects of these operations.

The clinical course and symptomatology are quite characteristic. The symptoms are related to a progressive mechanical obstruction of the esophagus and range from indefinite gastric symptoms, substernal distress and pain, varying degrees of dysphagia, regurgitation, and vomiting. Depending, of course, on the severity of these symptoms, there are an associated debility and malnutrition reaching severe states in patients in whom the mechanical obstruction has become practically complete. These severe symptoms and severe stages of malnutrition are chiefly associated with the large pulsion diverticula and rarely with the traction type. The traction type is most commonly seen in the midesophageal region associated with the hilar regions of the lungs and the various inflammatory conditions involving the lungs and the hilar nodes. They are produced by an extension of an adjacent inflammatory reaction to the wall of the esophagus, with traction and outpocketing of the entire thickness of the wall of the esophagus as the adjacent acute inflammatory reaction subsides and is replaced by scar and scar retraction. In this type the sac rarely hangs down in a dependent position in relation to the esophagus or is rarely large enough to angulate or obstruct the esophagus and cause the classical symptoms. Surgical intervention, therefore, is not indicated except for other complications primarily caused by the associated infection—periesophageal abscess or bronchial fistula. These complications, however, are much more commonly associated with carcinoma which, with considerable frequency, produces pseudodiverticula or esophagotracheal or esophagobronchial fistulas. If carcinoma can be ruled out by bronchoscopy and esophagoscopy and properly taken biopsy specimens, the surgical

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From the Department of Surgery, The Lahey Clinic.

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over a period of two years. Roentgenograms showed that the upper two-thirds of the esophagus was dilated; a large diverticulum, 8 by 8 cm., was present at the junction of the lower and middle thirds of the esophagus, with complete obstruction.

The patient was admitted to the hospital on Jan. 19, 1940, and on January 29, a transpleural diverticulopexy was done. He made an uneventful convalescence and was completely relieved of the symptoms. He returned to the clinic two years later with definite angina pectoris but no recurrence of difficulty in swallowing or regurgitation. Diagnosis was made of coronary sclerosis, and restricted activity and a medical regimen were advised.

The patient died in September, 1945, of coronary occlusion, about five years after operation for the diverticulum, without recurrence of the esophageal symptoms.

CASE 3.—A 72-year-old man was admitted to the clinic Jan. 15, 1940, complaining of retrosternal distress, dysphagia, regurgitation, and progressive loss of weight and strength of about three years' duration. Roentgenograms showed a large diverticulum in the lower third of the esophagus. The patient was in relatively poor general condition from extensive general arteriosclerosis and associated angina pectoris and pulmonary emphysema. In view of the serious esophageal symptoms, however, he was admitted to the hospital Jan. 15, 1940. On Jan. 19, 1940, a transpleural diverticulopexy was done, with complete relief of the esophageal symptoms until the present time.

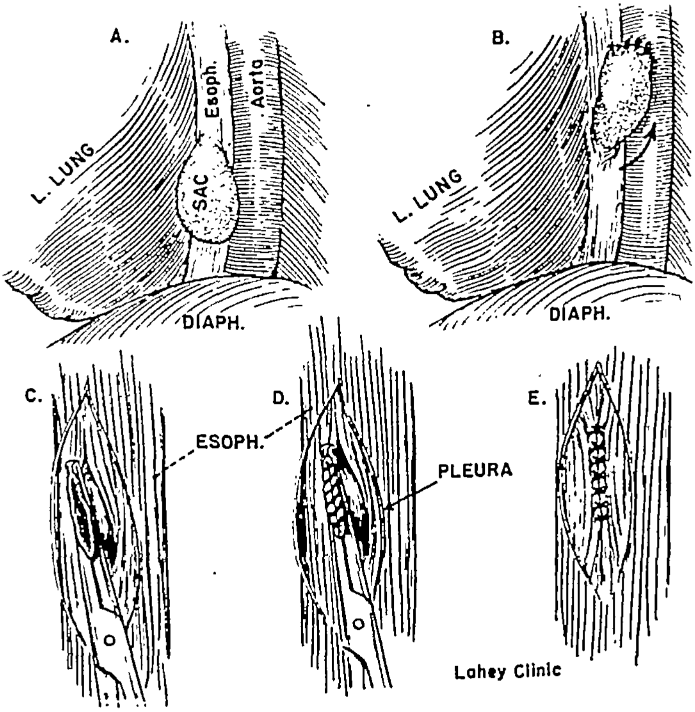

Fig. 4.—Sketches of the operative procedures for the treatment of thoracic diverticula. *A*, Sac in its usual dependent relation to the esophagus; *B*, elevation and fixation of the sac in diverticulopexy; *C*, *D*, and *E*, operative steps in one-stage excision of the sac.

In these three cases transpleural exposure was made through the left lower thorax, the mediastinal pleura overlying the diverticulum was opened, and the diverticulum and esophagus adjacent to the neck were mobilized. The apex of the sac was elevated along the long axis of the esophagus and sutured with fine silk to the pleura at the highest possible point of elevation which would not produce traction or any angulation of the esophagus itself (Fig. 4, A and B). This permitted free drainage of the sac at all times and prevented the large number of pulsion diverticula of the thoracic esophagus has been reported in the literature, there are very few references to specific surgical treatment of this lesion. Esophagoscopy, dilatation, sounding, lavage, and dietary management have been described, which, however, cannot be successful in the large, truly obstructing diverticula. Exclusive of those associated with diaphragmatic hernia, five patients have been operated upon at The Lahey Clinic who had large pulsion diverticula of the thoracic esophagus with marked symptoms of obstruction. Three of these diverticula occurred before the advent of penicillin and the patients were extremely bad risks because of extensive cardiovascular disease. In these cases a transthoracic diverticulopexy was done, with the patients' survival and complete relief of symptoms for their remaining years of life.

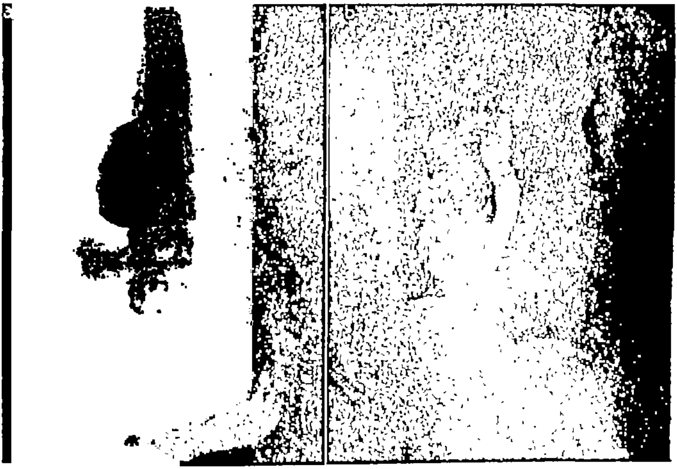

Fig. 3.—Barium study of the esophagus showing a large pulsion diverticulum of the lower thoracic esophagus. *a*, Preoperatively, the sac in a dependent obstructing position; *b*, postoperatively, showing adequate drainage and relief of obstruction following diverticulopexy.

REPORT OF CASES

CASE 1.—A man, 49 years of age, was admitted to the clinic Dec. 8, 1936, complaining of anorexia, dysphagia, vomiting, and progressive weight loss. Roentgenograms showed a large pulsion diverticulum, about 5 by 5 cm., of the lower third of the esophagus (Fig. 3, *a* and *b*). He was admitted to the hospital, and on Jan. 2, 1937, transthoracic diverticulopexy was done. Following this he made a good recovery and was completely relieved of the esophageal symptoms. He was readmitted to the hospital approximately one year later, however, with dyspnea, cough, severe hemoptysis, and fever, and died approximately one week after admission.

Post-mortem examination showed extensive miliary tuberculosis as the cause of death. The operative field was in satisfactory condition.

CASE 2.—A 61-year-old man was admitted to the clinic Jan. 18, 1940, complaining of pressure in the chest, dysphagia, and regurgitation of food; the symptoms had been progressive

Roentgenograms showed a very large diverticulum at the junction of the lower and middle thirds of the esophagus. He also had the clinical signs and symptoms of hyperthyroidism and the basal metabolic rate was plus 45. A diagnosis was made of primary hyperthyroidism and diverticulum of the thoracic esophagus (Fig. 6, *a* and *b*). He was placed on propylthiouracil and after proper preparation, he was readmitted in November, 1946. On Nov. 13, 1946, subtotal thyroidectomy was done.

Since at this time the hyperthyroidism was fully controlled, on November 26 a transthoracic excision of the esophageal diverticulum, one stage, was done. Convalescence was satisfactory and uneventful, and the patient had complete relief of the symptoms.

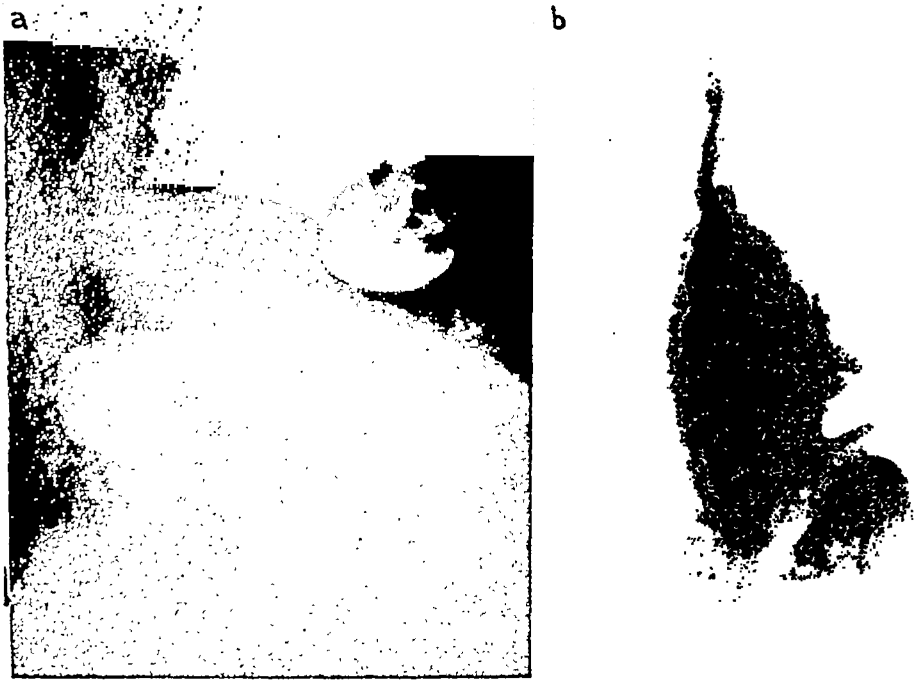

Fig. 6.—Barium study of a large obstructing diverticulum lying transversely behind the heart; *a*, preoperative roentgenogram; *b*, appearance after excision.

In these two cases the diet was restricted to high-caloric liquids, and penicillin was administered intramuscularly, 30,000 units every three hours for forty-eight hours prior to the operation. The operation was carried out through a wide transpleural posterolateral approach through the left lower thorax.

In Case 4 the diverticulum could be visualized lying immediately beneath the mediastinal pleura. The pleura was opened and the sac carefully and completely mobilized, dissecting back the thinned-out muscle fibers from around the neck of the diverticulum.

In Case 5, upon opening the thorax, the diverticulum could not be visualized since it lay transversely behind the pericardium. It became necessary to mobilize the lower third of the esophagus and to dissect this sac out carefully from the mediastinum. In this case as well, the muscle fragments were carefully dissected from the neck. A thin Kocher clamp was then placed across the neck into the sac about 0.5 cm. from the wall to allow sufficient tissue so that it might be turned in without encroaching on the lumen of the esophagus food from passing into the diverticulum, rather than into the esophagus proper, during deglutition. This surgical procedure proved to be a satisfactory method of managing these three cases of intrathoracic diverticula before the advent of penicillin. The danger of mediastinal and pleural contamination that would have been associated at that time with any attempt to excise the diverticulum would have been great and the extremely poor general status of these patients would have made a more prolonged procedure dangerous. The patients were completely relieved of symptoms for the duration of their lives (from one to six years).

In the past year, however, two younger patients have been seen who required operative treatment for relief of the symptoms of an obstructing thoracic esophageal diverticulum. In these cases the diverticulum was excised in one stage, in conjunction with intensive treatment with penicillin.

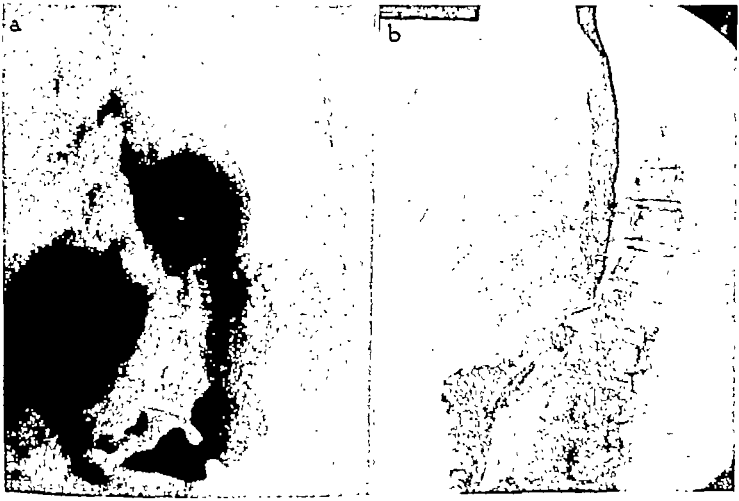

Fig 5.—Barium study of large obstructing pulsion diverticulum: *a*, preoperative appearance of the sac; *b*, appearance after excision.

CASE 4.—A woman, aged 47 years, was admitted to the clinic April 24, 1946, complaining of progressive dysphagia, regurgitation, vomiting, and loss of weight and strength over a period of ten years. Roentgenograms showed a large diverticulum of the lower third of the esophagus (Fig. 5, *a* and *b*).

The patient was admitted to the hospital on June 5, 1946. On June 7 a transpleural excision of the diverticulum in one stage was done. Following this procedure she made a very satisfactory recovery, with complete relief of the symptoms.

CASE 5.—A man, aged 53 years, was admitted to the clinic in August, 1946, complaining of regurgitation of food and retrosternal distress of about six months' duration. In addition, he had noted marked dyspnea, palpitation, tachycardia, nervousness, and weight loss.

TUBERCULOSIS AND PREGNANCY

AN ANALYSIS OF ONE HUNDRED EIGHTEEN CASES

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ABOUT a decade ago one of us[1] published a report of six cases of pulmonary tuberculosis complicated by pregnancy in which the delivery was by cesarean section. All of these patients had artificial pneumothorax at the time of delivery. At that time we felt that the tuberculous woman nearly always improved when she became pregnant unless there was some other complication. We felt that there was some factor in the delivery that caused the patient's tuberculosis to become worse after the baby was born. We did not know what this factor was. Since then, we have decided that the cause of the flare-up was the greatly increased intrapulmonary pressure that developed during the second stage of labor. It seems clear that incompletely healed tuberculous foci would be torn apart by this pressure, and reactivation of the inactive lesions would result.

Friedman and Garber[2] in an excellent review of the available and pertinent literature on the subject have pointed out the wide difference of opinion as to the effect that pregnancy has on tuberculosis. In reviewing the literature, we have classified the articles into seven groups as follows: Group I,[3-36] which believed that pregnancy was either beneficial or harmless; Group II,[37-72, 160] which believed that pregnancy was harmful; Group III,[73-91] which believed the patient was better during pregnancy but became worse after delivery; Group IV,[95-116] which believed delivery was harmful; Group V,[117-121] which believed lactation produced the harmful effects; Group VI,[122-136] which believed the type of disease (caseous pneumonic, exudative, or proliferative) was the chief deciding factor; and finally, Group VII, [137-159, 160] which believed that collapse therapy enhanced the chances of a favorable outcome in patients with tuberculosis and pregnancy.

In Group I the reasons given for the improvement were: "(a) Mother fixes more nitrogen[7]; (b) She utilizes in a better manner the sulphur of her albumenoids and the iron of her food and at the same time mobilizes a larger quantity of phosphorus and lime; (c) more oxygen is consumed and more carbon dioxide produced. All of this forms a hyper nutrition which is beneficial to the mother;" (d) increased intra-abdominal pressure acts on the lung like phrenic avulsion or artificial pneumothorax, [23, 24, 25] or pneumoperitoneum[26]; (e) presence of gonadotrophic hormone in pregnant women[27] and (f) "all the physiological

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From the Departments of Medicine and Obstetrics of the Vanderbilt University School of Medicine.

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itself. A second Kocher clamp was placed adjacent to this and the diverticulum removed between these clamps, after carefully walling off the entire pleura and surrounding tissues with cellophane-lined gauze pads (Fig. 4, C, D, and E). The mucosal layer contained in the thin Kocher clamp was then closed by a running over-and-over suture of fine chromic catgut, and the mucosa closed by drawing up on this running suture as the Kocher clamp was removed, thereby accomplishing a relatively aseptic closure of the mucosal layer. The muscular layers of the esophagus were then closed with fine interrupted silk sutures. The esophagus was then returned to its bed in the mediastinum, the mediastinal tissues were sprayed with 100,000 units of penicillin solution, and the mediastinal pleura was closed. Another 100,000 units of penicillin were sprayed throughout the pleural cavity, the lung re-expanded, and the chest and the thorax closed, leaving an intercostal catheter for suction to aid in rapid re-expansion of the lung. The patient was placed on 40,000 units of penicillin intramuscularly for ten days following operation, and the intake by mouth was restricted and graduated much in the same manner as in the management of a patient who has had a gastric resection.

By this technique convalescence in these cases was uneventful without complication or residual infection. All of these patients obtained complete and lasting relief from the esophageal symptoms. Although there may still be an occasional specific indication for the use of the diverticulopexy type of operation, it is recommended that, with proper use of penicillin, transpleural excision of the diverticulum by the described technique, in one stage, is the operation of choice.* This operation is recommended and should be carried out on all patients suffering from symptoms of esophageal obstruction which arises from a diverticulum of the thoracic esophagus.

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*Since this paper was submitted for publication, three additional patients have been operated upon by this method.

In Group VI the opinion was almost unanimous that the most important factor in the harmful effects of pregnancy and the puerperium is exudative and caseous tuberculosis, except in the far advanced with obviously poor prognosis.[122-136]

There is ample evidence[137-156] that pregnant women whose lungs are successfully collapsed stand spontaneous delivery well in most cases. It seems that those with pneumothorax stand delivery better than those with thoracoplasties. Scadding[152] reported spontaneous delivery in a woman with oleothorax without harmful effect.

Our experience has led us to agree with Group III which believed the patient was better during pregnancy but became worse after delivery. The only serious effort to establish the cause of improvement of the tuberculosis during pregnancy is the work of Steinbach and Klein.[27] They showed that the gonadotropic hormone which appears in pregnancy was responsible for increased resistance to tuberculosis in rabbits and guinea pigs. It seems probable that there are other factors involved in this improvement, but no reasonable evidence of such factors has been produced.

In our opinion DeLee, as quoted by Funk,[96] and Jameson[103] came nearer to the real cause of the harmful effects of pregnancy and the puerperium on tuberculosis than anyone else. DeLee said "straining at labor may break down practically healed lesions." Jameson[103] pointed out "the importance of the reduction of voluntary effort in the second stage of labor which results in increased intrapulmonary pressure." Realizing that the tuberculous disease involves mainly the elastic tissue portions of the lungs, we feel that it is obvious that the greatly increased intrapulmonary pressure which develops during the second stage of labor is most likely to tear open partially healed tuberculous lesions. So far as we know, the intrapulmonary pressure during the second stage of labor has never been measured. It has been demonstrated, however, that the intranasal pressure during[153] forced expiration may reach as high as plus 87 to 100 mm.[157] of mercury. We believe it is probable that the intrapulmonary pressure during the second stage of labor is equal to those quoted and possibly even greater at times. This pressure is great enough to tear open partially healed tuberculous lesions.

With these facts in mind, it occurred to us that the harmful effects of pregnancy and the puerperium could be avoided by eliminating the increased intrapulmonary pressure that develops during labor, particularly the second stage. The most obvious way to do this was delivery by cesarean section. This procedure was first suggested by Dr. Charles Sidney Burwell, who recommended it in the case of a tuberculous woman in active labor who at the same time was having a severe pulmonary hemorrhage. It worked satisfactorily in this case, and we felt that it could be used to advantage in selected cases to avoid the harmful effects of delivery.

We later decided that in suitable cases, the delivery might be allowed to progress to the second stage, and then forceps used after the dilatation was complete, and more recently we have employed continuous caudal or continuous spinal analgesia with the final extraction of the baby with forceps.

processes in the pregnant woman are functioning at their best during this time.[20]''

In Group II the reasons given for the harmful effects of pregnancy were: (a) Increased demands on metabolism, oxygenation and innervation, on circulation and elimination[38, 39, 41, 45, 50, 60, 67, 68]; (b) point of least resistance is put to test; (c) presence of the gravid uterus interferes with respiration and aeration of blood; (d) nausea and vomiting of pregnancy tend to interfere with assimilation; (e) prolonged muscular exertion of labor, loss of blood and attending exhaustion, use of anesthetics, auto infection by the aspiration of infected material from an old focus in the lung into healthy portions, and the *possibility of toxins thrown into the system from the placental site*; (f) strain of subsequent lactation and responsibility incident to the care of the child; (g) hepatic insufficiency[42]; (h) ''pregnancy seems to reduce the natural defense forces[47];'' (i) ''the depressive and damaging action on the adrenals and other glands[31];'' (j) ''upward displacement of the diaphragm[33];'' (k) ''decreased lipolytic *activity of the blood causes difficulty in dissolving fatty capsules of* bacilli;'' (l) ''increased cholesterol content of the blood on which tubercle bacilli thrive;'' (m) decalcification liberates bacilli; (n) increased basal metabolic rate[53]; (o) renal adequacy declines; (p) reduced tuberculin reactivity[50]; (q) respiratory rate increased; (r) alteration in the permeability of the capillaries; (s) *contraction of the thorax*[61]; (t) tissue changes in the lungs and air passages; (u) strength of woman is diminished[65]; (v) ''the blood of the pregnant woman is full of lipoids which favor the growth of tubercle bacilli and anatomical changes in the mucous membranes of the body, especially the larynx and bronchi which favor the development of tuberculosis.[72]''

In Group III the explanations of the patients' getting worse after delivery following pregnancy during which their condition improved were as follows: (a) ''A great tendency to hemorrhage during puerperium[73];'' (b) ''straining and increased blood pressure incident to labor probably converts partially healed lesions into open ones, thus liberating tubercle bacilli in large numbers[74];'' ''many free organisms are thrown into the blood stream[3]; actual physiologic exhaustion[3], the congestion of the lungs incident to labor; possible loss of blood; and effects of anaesthetic (if one has been used;'' (c) ''cardiac failure and pulmonary edema[76];'' (d) ''abrupt displacement of the diaphragm coincident with the emptying of the uterus[77, 81, 85-88];'' (e) ''the change in intrathoracic mechanics during pregnancy accounts for the improvement in the pulmonary condition during the latter months of pregnancy and ill effects which are often noted after parturition.[83]''

In Group IV the reasons given for the harmful effects of delivery were: (a) ''Cardiac failure and pulmonary edema and hemorrhage[95];'' (b) ''*straining at labor may break down practically healed lesions,*[96]'' ''actual physiological exhaustion following labor;'' (c) ''increased capillary permeability which is known to occur at this time.''[98]

Group V believed that lactation is dangerous to both mother and child and should not be permitted.[117-121]

this group were worse postoperatively. Of the 3 that were worse, 2 had active, bilateral, far-advanced disease with positive sputum, and poor prognosis. One of these two died five days after delivery, of massive pulmonary hemorrhage. The pneumothorax was of only thirty-five days' duration and was done for the control of pulmonary bleeding; the other one died of tuberculosis thirty days after delivery. The pneumothorax was of only five days' duration, and was done for the control of pulmonary hemorrhage. Both of these patients probably would have died of hemorrhage during labor if they had not had cesarean section. The third one had controlled pulmonary disease with negative sputum, but active pleurisy with effusion (positive for tubercle bacilli) complicating the pneumothorax. She has been lost to follow-up study, but the Tennessee Bureau of Vital Statistics has no record of her death after three years.

There were 2 patients whose lungs were expanded after artificial pneumothorax, and one of these did satisfactorily after delivery and one was worse. The one that was worse had the lung re-expanded because the collapse was unsatisfactory, and the opposite lung had far-advanced disease. She was extremely sick at the time of delivery and is presumed to be dead. There was no follow-up on her.

There were 3 patients in Group 1 who had had thoracoplasties and all 3 of them had satisfactory postoperative courses.

There were 4 patients in Group 1 who had phrenic paralysis; 1 of them had a satisfactory postoperative course, and the other 3 were worse. Two of the patients whose postoperative courses were worse had bilateral far-advanced disease with positive sputum and hopeless prognosis. One of them died of tuberculous meningitis three months after operation. The other died of tuberculosis nine months after operation. The third one had moderately advanced disease, and died of tuberculosis twenty-seven months after operation.

TABLE II. GROUP 2

	CESAREAN SECTION WITHOUT COLLAPSE						
	NO. OF CASES	POST-OPERATIVE COURSE SATISFACTORY	POST-OPERATIVE COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	DIED LATER	PROBABLY DIED LATER	ALIVE 11 YEARS LATER QUIESCENT
Totals	21	19	2	0	1*	0	1†

*Died of tuberculosis three months after operation. She had an acute exudative extension of her disease.

†Alive eleven years later with a positive sputum. She is doing part of her housework.

There were 21 cases in Group 2 (Table II); 19 of these patients had satisfactory postoperative courses, and 2 were worse. Both of those that were worse had active bilateral disease with positive sputum; one of them had acute exudative extension of the disease and died of tuberculosis three months after operation. The other is alive eleven years after delivery but still has a positive sputum although she is doing part of her housework.

There were 15 patients in Group 3 (Table III); all of them had satisfactory post-partum courses.

The purpose of our study was to see if these methods of delivery were satisfactory, and if they had any harmful effect on the progress of the pulmonary tuberculosis, and to see if one method was more satisfactory than another. It also was our purpose to show that therapeutic abortions, because of pulmonary tuberculosis, were rarely justified. We further were impressed by the assertion[123, 126, 128] that only exudative and caseous pneumonic tuberculosis did badly with pregnancy and we wanted to see if our experience coincided with this. We hoped to be able to establish indications for the different methods of delivery; and finally, we hoped to be able to accumulate data on the effect of the greatly increased intrapulmonary pressure on pulmonary tuberculosis.

The material studied included 118 patients, divided into eight groups as follows: (1) cesarean section with collapse; (2) cesarean section without collapse; (3) forceps delivery with collapse; (4) forceps delivery without collapse; (5) spontaneous delivery with collapse; (6) spontaneous delivery without collapse; (7) therapeutic interruption of pregnancy, hysterotomy; and (8) spontaneous abortion.

CRITERIA OF SATISFACTORY POST-PARTUM AND POSTOPERATIVE PROGRESS

The criteria of satisfactory post-partum and postoperative progress were: (1) no increase in temperature or pulse rate (except immediately postoperative or post partum) in three months after delivery; (2) no reversal of negative sputum to positive in three months after delivery; (3) no nonpulmonary tuberculous complications in three months after delivery; (4) no x-ray evidence of progression of the tuberculous lesion in three months after delivery.

There were 34 patients in Group 1 (Table I); 25 had artificial pneumothorax, and 1 of them had bilateral pneumothorax; 22 of these, including the one with bilateral pneumothorax, had satisfactory postoperative courses. Three of

TABLE I. GROUP 1

CESAREAN SECTION WITH COLLAPSE							
	NO. OF CASES	POST-OPERATIVE COURSE SATISFACTORY	POST-OPERATIVE COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	NOT ACCOUNTED FOR	DIED LATER	PROBABLY DIED LATER
Artificial pneumothorax	25	22	3	0	1*	2†	0
Expanded	2	1	1	0	0	0	1‡
Thoracoplasty	3	3	0	0	0	0	0
Phrenic	4	1	3	0	0	3§	
Totals	34	27	7	0	1	5	1

*The one not accounted for had negative sputum, but had pleural effusion that contained tubercle bacilli and the postoperative course was stormy. No death record after three years.

†One died of massive pulmonary hemorrhage five days after operation. The other died of tuberculosis thirty days after operation. Both had pneumothorax for a few days only (five to thirty days) to control hemorrhage.

‡Lung re-expanded because collapse was unsatisfactory and the other lung had far-advanced disease; sputum was positive.

§Two of the three had far-advanced bilateral disease with positive sputum and hopeless prognosis; one of them died three months postoperatively of tuberculous meningitis; the other died of tuberculosis nine months after operation. The third one had moderately advanced disease with positive sputum and died of tuberculosis twenty-seven months after operation.

TABLE V. GROUP 5

SPONTANEOUS DELIVERY WITH COLLAPSE						
	NO. OF CASES	POST-PARTUM COURSE SATISFACTORY	POST-PARTUM COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	DIED LATER	PROBABLY DIED LATER
Artificial pneumothorax	7	6	1	0	1*	0
Thoracoplasty	1	1	0	0	0	0
Phrenic	1	1	0	0	0	0
Totals	9	8	1	0	1	0

*She died of tuberculosis twelve months later. She had an unclosed cavity in the right base and positive sputum.

thoracoplasty and a temporary phrenic paralysis; both of them had satisfactory post-partum courses.

Group 6 (Table VI) consisted of 20 patients, 18 of whom had satisfactory post-partum courses. The 2 whose post-partum courses were worse had far-advanced bilateral active tuberculosis with positive sputum. One of them had far-advanced bilateral exudative disease with massive effusion on the left, and the other had far-advanced bilateral proliferative disease with multiple cavities. Each was considered to have a hopeless prognosis.

TABLE VI. GROUP 6

SPONTANEOUS DELIVERY WITHOUT COLLAPSE						
	NO. OF CASES	POST-PARTUM COURSE SATISFACTORY	POST-PARTUM COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	DIED LATER	PROBABLY DIED LATER
Totals	20	18	2	0	2*	0

*One of these had bilateral far-advanced exudative disease and massive effusion on the left. She died six months later of tuberculous meningitis. The other had far-advanced bilateral proliferative disease with cavities in both lungs. She died of tuberculosis thirty-nine days after delivery. Each of these patients had a hopeless prognosis.

Group 7 (Table VII) consisted of 4 patients, and there was 1 each who had artificial pneumothorax, thoracoplasty, phrenic paralysis, and no collapse.

TABLE VII. GROUP 7

THERAPEUTIC INTERRUPTION OF PREGNANCY, HYSTEROTOMY							
	NO. OF CASES	POST-OPERATIVE COURSE SATISFACTORY	POST-OPERATIVE COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	NOT ACCOUNTED FOR	DIED LATER	PROBABLY DIED LATER
Artificial pneumothorax	1	1*	0	0	0	1	0
Thoracoplasty	1	1†	0	0	0	0	0
Phrenic	1	1‡	0	0	0	0	0
No collapse	1	1§	0	0	0	0	0
Totals	4	4	0	0	0	1	0

*Died seven and one-half years later of tuberculosis.
†Progress satisfactory nine months later.
‡Disease has spread and she is worse three years later.
§Disease arrested ten years after hysterotomy.

TABLE III. GROUP 3

FORCEPS DELIVERY WITH COLLAPSE

	NO. OF CASES	POST-PARTUM COURSE SATISFACTORY	POST-PARTUM COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	DIED LATER	PROBABLY DIED LATER
Art. Pneumo. without continuous caudal	5	5	0	0	0	0
Art. Pneumo. with continuous caudal or spinal	7	7	0	0	0	0
Thoracoplasty	2	2	0	0	0	0
Phrenic	1	1	0	0	0	0
Totals	15	15	0	0	0	0

Group 4 (Table IV) consisted of 12 patients, 10 of whom had satisfactory post-partum courses; 2 of them were worse. One of these two had bilateral far-advanced active exudative disease with positive sputum and she died of tuberculosis seven months later. The disease was hematogenous and resembled miliary tuberculosis. The other had moderately advanced exudative disease with positive sputum and congestive heart failure. There is no record of her death in the Tennessee Bureau of Vital Statistics, and we have lost track of her. We presume she is dead. Four of this group had continuous caudal or spinal analgesia, and all 4 had satisfactory post-partum courses. There were 11 forceps deliveries in Groups 3 and 4, in which forceps were employed merely for the final extraction of the baby after dilatation was complete. These patients had continuous caudal or spinal analgesia and were unable to expel the baby because of the anesthesia.

TABLE IV. GROUP 4

FORCEPS DELIVERY WITHOUT COLLAPSE

	NO. OF CASES	POST-PARTUM COURSE SATISFACTORY	POST-PARTUM COURSE WORSE	MATERNAL DEATHS FROM DELIVERY	DIED LATER	PROBABLY DIED LATER
Without continuous caudal	8	6	2	0	1*	1†
With continuous caudal or spinal	4	4	0	0	0	0
Totals	12	10	2	0	1	1

*Died of tuberculosis seven months after delivery. At the time of delivery the disease was hematogenous and acute.

†Had moderately advanced active exudative disease with congestive heart failure at the time of delivery and is presumed to be dead although no record of her death can be found.

Group 5 (Table V) consisted of 9 patients, 8 of whom had satisfactory post-partum courses. The 1 patient whose post-partum course was worse was one of 7 pneumothorax cases. She had far-advanced right lower lobe disease with a large unclosed cavity and positive sputum. She died of tuberculosis twelve months later. There was 1 patient each in this group who had a time of delivery. The pulmonary disease was proliferative, far-advanced unilateral.

4. One (Case 52) had reactivation of arrested tuberculosis with spread to the opposite side. The baby was delivered by forceps without continuous caudal or spinal analgesia.

5. One (Case 58) had tuberculous peritonitis and tuberculous pleurisy complicating the pneumothorax at the time of the cesarean section.

6. One (Case 64) had massive collapse of the diseased lung following cesarean section. She had no therapeutic collapse and the postoperative course otherwise was not remarkable.

7. One (Case 94) had tuberculous meningitis two months after delivery by cesarean section. She had had phrenic paralysis for two months at the time of delivery. The disease was proliferative and far advanced.

8. One (Case 3) had tuberculosis of spine and kidney and congestive heart failure. She was delivered by low forceps; no follow-up was made. The disease was far-advanced proliferative.

DISCUSSION

It is worthy of note that only 4 of our 118 patients had the pregnancies interrupted deliberately.

It is clear that the 14 patients who were worse after delivery were practically hopelessly sick with tuberculosis and had little, if any, chance for survival even if they had not been pregnant. The fact that two of them are alive is testimony to the efficacy of the method by which they were managed.

It will be seen, by comparing tables, that of the 14 whose progress was worse after delivery, there were 7 of 34 who had cesarean section with collapse (20.6 per cent); and that 2 of 21 had cesarean section without collapse (9.4 per cent); none of the 14 had forceps delivery with collapse; 2 of 12 had forceps delivery without collapse (16.6 per cent), and both of them were delivered without continuous caudal or spinal analgesia; 1 of 9 had spontaneous delivery with collapse (11.1 per cent); 2 of 20 had spontaneous delivery without collapse (10 per cent). One might conclude from these findings that cesarean section delivery was the least satisfactory method and that spontaneous delivery was the best. While this might seem true, it is not so if we consider the fact that the patients in the cesarean section delivery group had the poorest prognosis from the standpoint of the tuberculosis, and that those in the spontaneous group had the best prognosis. The entire forceps delivery group of patients had almost the same percentage of unfavorable courses after delivery as the spontaneous delivery group, but when we separate the continuous caudal or spinal patients from those without continuous analgesia, there is a marked difference; none of the patients in the continuous caudal and spinal group was worse, while the rest of the forceps group had 12.5 per cent worse. It is noteworthy that the prognosis of patients in this entire group occupied an intermediate position with the other two groups; that is, the cesarean delivery group and the spontaneous delivery group. In fact, the progress of the three groups reflects the prognosis from the standpoint of the tuberculosis.

All of them had hysterotomies, and they all did satisfactorily after their operations. Therapeutic interruption was considered indicated because in one case there was active exudative moderately advanced pulmonary tuberculosis, with positive sputum, rheumatic heart disease, and syphilis; another had far-advanced bilateral disease with a thoracoplasty on the left and the disease was so widespread that we feared she could not undergo any of the methods of delivery without great danger to herself. We were influenced greatly in the latter case by the fact that her vital capacity was only about 1,200 c.c. and she occasionally had slight elevations of temperature. She had a hysterotomy and sterilization. The other two had active bilateral far-advanced proliferative disease with multiple cavities and a considerable amount of fever daily. We felt that they probably would not survive the period of their pregnancy and that they would probably abort spontaneously because of the high fever. They had grown worse after becoming pregnant, which was further reason for emptying the uterus. The patient (see footnote to Table VII‡) in this group who had a temporary phrenic paralysis with the exudative pulmonary tuberculosis, rheumatic heart disease, and syphilis is alive three years later, but the tuberculosis has spread considerably and her outlook is poor. The one (see footnote to Table VII†) who had had a thoracoplasty and bilateral far-advanced disease is progressing satisfactorily nine months after operation. One of those (see footnote to Table VII) with far-advanced bilateral proliferative disease with pneumothorax and high daily fever died of tuberculosis seven and one-half years later. The one with no collapse (see footnote to Table VII§) is reported to have the disease arrested about ten years later.

Group 8 (Table VIII) consisted of three patients. Two of them had syphilis which was considered the cause of the spontaneous abortion and no cause was discoverable for the other one. They have not been followed.

TABLE VIII. GROUP 8

SPONTANEOUS ABORTION				
	NO. OF CASES	POST-PARTUM COURSE SATISFACTORY	POST-PARTUM COURSE WORSE	MATERNAL DEATHS FROM DELIVERY
Artificial pneumothorax	1	1	0	0
No collapse	2	2	0	0
Totals	3	3	0	0

No follow-up on any of this group.

COMPLICATIONS

Eight of our tuberculous patients had other complications than pregnancy.

1. One (Case 77) had a pleural effusion containing tubercle bacilli before cesarean section, complicating an artificial pneumothorax of nine months' duration. She had proliferative pulmonary disease with negative sputum.

2. One (Case 90) had a nontuberculous wound infection following cesarean section. She also had pleural effusion. The pulmonary disease was proliferative and it was eventually controlled as was the pleural effusion.

3. One (Case 6) developed tuberculous empyema nine months after cesarean section. The artificial pneumothorax was of only one month's duration at the

In our series of 118 cases, we experienced a mortality rate of 9.3 per cent, which appears to be extremely low when compared to a series of 85 cases studied by Ornstein Ulmar and Dittler as reported by Falls, which experienced a mortality rate of 36 per cent in five years, and is favorably comparable to a series of 82 cases reported by Ornstein and Epstein[128] which experienced a mortality rate of 14.6 per cent. If we count as dead the two patients who probably died, our mortality rate would be 11 per cent.

We are inclined to consider these statistics of little significance. It is our opinion that none of these patients had the course of the tuberculosis influenced adversely by the methods of delivery employed since those who died and those who are presumed to have died would certainly have done so even if they had not been pregnant. The extent of the disease and the degree of the activity would have made such an outcome almost inevitable.

SUMMARY

We believe from our experience that the methods of delivery we have employed are satisfactory. Despite the fact that our patients with cesarean section delivery had the worst record, we believe this method is the one of choice in the worst cases. Objection has been voiced to this procedure because of the high mortality rate from cesarean section. The answer to this objection is that the mortality rates from this procedure are based on all types of cesarean deliveries, including emergencies, those patients who have been in labor many days, those who have had presenting hands, cords, feets, etc., and those who have had one or more vaginal examinations.

We decide early in the course of pregnancy with our patients that cesarean section will be the method of delivery, and their care is directed toward this end. They are delivered at term or just before term, and are sterilized if further pregnancies are considered undesirable or dangerous. The fact that we had no operative mortality in 55 patients is testimony to the safety of this procedure when employed deliberately in patients who are properly prepared for it. A close second, in our opinion, is delivery by continuous caudal or continuous spinal analgesia with low forceps extraction, when dilatation is complete. It is possible that further experience may lead us to believe that this method is better than cesarean section. When the anesthesia is satisfactory, the patients experience no inconvenience or pain and are not exhausted by the delivery.

While our tables show good results in those patients delivered by forceps without continuous caudal or continuous spinal analgesia, we believe it is not a good method of delivery in active and uncontrolled tuberculosis, because there is some bearing down and consequent increased intrapulmonary pressure during the first stage of labor.

We are convinced, from our experience, that therapeutic interruptions of pregnancy are seldom justified because of pulmonary tuberculosis and should be reserved for those patients in whom pregnancy itself is difficult and those in whom the other complications of pregnancy are serious. It should be used

The 97 patients in our series who did satisfactorily after delivery were classified when they came under our observation according to the N.T.A. Classification as follows: 23 were far-advanced active with mainly proliferative disease and 16 were far-advanced active with mainly exudative disease; 17 were moderately advanced active with mainly proliferative disease, and 2 were moderately advanced active with mainly exudative disease; 4 were minimal active with mainly proliferative disease; 11 were far-advanced inactive with mainly proliferative disease; 22 were moderately advanced inactive with mainly proliferative disease; and 12 were minimal inactive with mainly proliferative disease. All those patients who could not be classified as having disease arrested were classified as active because we felt that if they had not been stable long enough to be considered arrested, the effect of labor would likely be the same as it would if they were "frankly" active.

Seventeen of the 97 patients who did satisfactorily after delivery had positive sputum at the time their babies were born (Table IX). Three of them had exudative disease which agrees with the experience of Ornstein and Kovnat[125, 126] and others that those with exudative tuberculosis may stand pregnancy well. Fourteen of these patients had mainly productive disease with some exudate. Eleven had satisfactory *artificial pneumothorax* and 1 of these had exudative disease. Of these 11, 5 were delivered by cesarean section, 4 by forceps, and 2 spontaneously. Two of these positive sputum patients had *thoracoplasty* and both had productive lesions; 1 was delivered by cesarean section and 1 delivered spontaneously. One of this group had *phrenic paralysis* and delivered spontaneously. There were 3 patients in this positive sputum group who had *no collapse,* but were classified as quiescent. Two of them had exudative disease and 1 had the productive type; 1 of these was delivered by cesarean section and 2 by forceps.

The difference in the post-partum course of this latter group and the group of 14 patients who did poorly after delivery seems to be that they had the disease controlled in contrast to the fact that the other group had progressive uncontrolled disease. And furthermore, we believe that the way in which these 17 cases were managed contributed a lot to their favorable progress.

TABLE IX

CLASSIFICATION OF NINETY-SEVEN PATIENTS WITH SATISFACTORY POST-PARTUM COURSES

Far Advanced:		
Active, mainly proliferative	23	
Active, mainly exudative	6	
Inactive, mainly proliferative	11	
Total		40
Moderately Advanced:		
Active, mainly proliferative	17	
Active, mainly exudative	2	
Inactive mainly proliferative	22	
Total		41
Minimal:		
Active, mainly proliferative	4	
Inactive, mainly proliferative	12	
Total		16

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in those cases of pulmonary tuberculosis in which the patient shows little resistance to the tuberculosis and is obviously or apparently unable to cope with the disease. It should not be employed after the third month of pregnancy because it is our observation and that of others[18, 34, 140, 153] that after the first trimester therapeutic interruption of pregnancy is as serious as delivery at full term and probably more so than delivery by one of the methods we have discussed here.

While we are impressed by the observation that[125, 126, 128] only exudative and caseous pneumonic cases do badly with pregnancy, we note that three of our patients who did well after delivery had exudative tuberculosis and positive sputum. We believe, however, that they would not have had satisfactory progress if they had not been controlled as outlined here; we also note that most of our patients who were worse after delivery had proliferative disease that was progressive; therefore, we believe that control of the disease is of more importance than the type of the disease.

We have tried to develop indications for the different methods of delivery and we believe the patients with the worse prognosis should have cesarean section. We believe further that continuous caudal analgesia and continuous spinal analgesia should be used in patients with better prognosis where there is less danger of reactivation of the tuberculosis. This would include those whose tuberculosis is quiescent by the N.T.A. Classification. Forceps delivery without continuous caudal or spinal analgesia may be used in quiescent or better cases where the analgesia is not effective and it is desirable to avoid the second stage of labor. Spontaneous delivery should be reserved for multiparous women whose tuberculosis has been arrested for more than one year, and whose histories indicate short easy labors. Primipara may be allowed to deliver spontaneously if the disease is apparently cured. Therapeutic interruption of pregnancy should never be done except in extreme cases in which pregnancy without tuberculosis would be difficult, and in those in whom the other complications are serious.

It is most difficult to show that the second stage of labor, with its increased intrapulmonary pressure, is responsible for the harmful effects of pregnancy and the puerperium; however, the fact that 52 of our 97 patients with satisfactory post-partum courses were active and 17 of them had positive sputum lends support to the belief when we remember that their deliveries were conducted in such a way as to eliminate or minimize the effects of this pressure.

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SPONTANEOUS COLLAPSE

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THE infiltration of air into tissue and the bursting of air into the thoracic and abdominal cavities have been reported separately in medical literature. In this treatise the subject of the abnormal presence of air in different anatomic areas is examined connectively, since air often migrates or flows from one area to another. The presence of extraneous air has been diagnosed as interstitial emphysema, spontaneous mediastinal emphysema, subcutaneous emphysema, spontaneous pneumothorax, and in this report an exceptional condition is diagnosed as spontaneous pulmonary pneumoperitoneum. The presence of air and blood, or just blood, in the thoracic cavity has induced conditions which are characterized as hemorrhagic pleurisy, spontaneous hemopneumothorax, and spontaneous hemothorax. The latter diagnosis is made because air has been absorbed before its presence has been demonstrated. All of the aforementioned pneumatic conditions are not common or well known. The absence of essential air in pulmonary tissue occurs in spontaneous atelectatic (massive) collapse. This pathologic entity must be differentiated from spontaneous collapse caused by the presence of extraneous air.

SPONTANEOUS INTERSTITIAL EMPHYSEMA

Interstitial emphysema is the precursor of spontaneous mediastinal emphysema, spontaneous pneumothorax, and subcutaneous emphysema. When alveoli rupture, air spreads along the connective tissue bands, which surround the bronchi and blood vessels of the lung. This may occur without trauma or markedly increased intrapulmonary pressure. It does occur after trauma, after some postoperative procedures, and with pulmonary infections. It is often associated with bronchopneumonia, influenza, pertussis, measles, and bronchial asthma. Congenitally thin alveolar walls, or walls weakened by disease, collapse spontaneously when intrapulmonary pressure is increased by coughing or straining. Uncontrollable cough caused the rupture of alveoli in the cases herein reported. On the other hand, interstitial emphysema may be one of the causes of incessant coughing. Macklin[1] demonstrated interstitial emphysema, which is the genesis of spontaneous mediastinal emphysema, by artificially increasing the intrapulmonary pressure in animals. He showed that air enters the perivascular sheaths of the finer branches of the pulmonary vessels. As the intrapulmonary pressure increases, the bubbles of air coalesce into larger ones and move toward the root of the lung. At the root, the air bubbles merge into large blebs which rupture into the mediastinum or produce a pneumothorax. Extraneous air may do both simultaneously. Ballon and Francis[2] and Macklin[1] described the course of air into the neck, face, axilla, anterior chest wall, arms, alongside of the

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From Boehne Tuberculosis Hospital.
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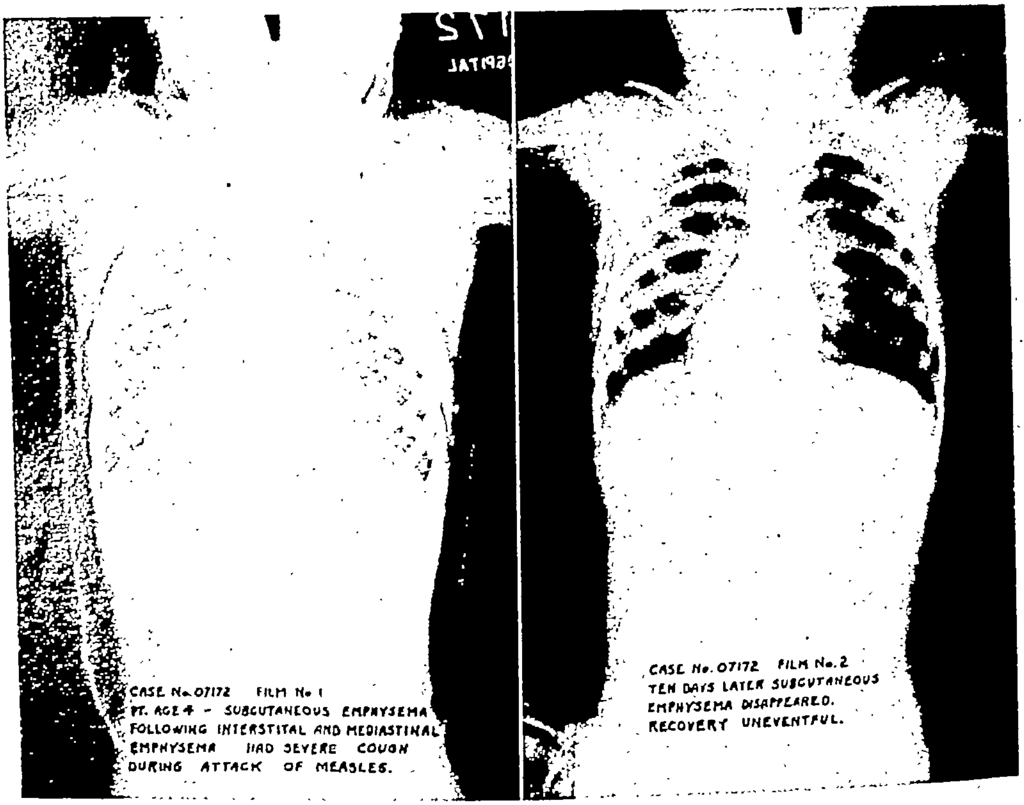
occurred without tracheotomy. Both had acute obstructive laryngitis. He did not know how air entered the pericardial sac and reported that Macklin had never found this condition in his experiments. It is doubtful whether mediastinal air with its origin from interstitial emphysema can extend into the pericardial space for anatomic reasons. Beck[34] said that an opening in the pericardium would have to be present to admit air. Etiologic factors of pneumopericardium are trauma, pericarditis, infection with gas bacillus, erosion and perforation of disease processes from neighboring air-containing organs, radium necrosis, and congenital defects.


CASE No. 07172 FILM No. 1
PT. AGE 4 - SUBCUTANEOUS EMPHYSEMA FOLLOWING INTERSTITAL AND MEDIASTINAL EMPHYSEMA HAD SEVERE COUGH DURING ATTACK OF MEASLES.
CASE No. 07172 FILM No. 2
TEN DAYS LATER SUBCUTANEOUS EMPHYSEMA DISAPPEARED. RECOVERY UNEVENTFUL.

A. B.

Fig. 1.—*A*, Subcutaneous emphysema following interstitial and mediastinal emphysema. *B*, Ten days after subcutaneous emphysema had disappeared.

Clinically, mediastinal emphysema may be suspected by palpating the subcutaneous tissue of the neck. This extraneous air gives the patient a tight feeling about the neck, even when it is confined to one side. Of course, the subjective feeling of compression is much more distressing when air infiltrates the neck bilaterally. The patient is apprehensive and complains of choking and difficulty in deglutition. Pain and distress referred to the mediastinum are commensurate with the amount of distention and pressure. Macklin[1] thought that, when the initial pain is lateral, the origin is in the interstitial tissue or pleura rather than in the mediastinum. The migration of air into the neck and subcutaneous tissue acts as a safety valve, and prevents tamponade on the trachea, elevating the tongue, or downward into the retroperitoneal space around the kidney. Fischer and Macklin[3] supported the theory that overdistention of the opposite lung could cause mediastinal emphysema.

The terms interstitial and mediastinal emphysema have been employed interchangeably in the literature. Reports on cases of subcutaneous emphysema and surgical emphysema discuss interstitial and mediastinal emphysema. Interstitial emphysema per se cannot be described clinically. Subcutaneous emphysema is often a definite sign of interstitial and mediastinal emphysema. Therefore, the general use of the term mediastinal emphysema, which can be demonstrated by both physical and x-ray examination, would at least clarify topic nomenclature.

SPONTANEOUS MEDIASTINAL EMPHYSEMA

In 1831 Laennec[4] described curious grating sounds and bubbling râles during respiration as diagnostic signs of subpleural and interlobar emphysema of the lung. These signs were confirmed by Skoda[5] in 1850. Six years later Rokitansky[6] described the pathologic anatomy of mediastinal emphysema which followed pulmonary trauma and ulceration of the trachea.

Muller[7] in 1888 described physical signs characteristic of pneumomediastinum: namely, the presence over the precordium of bubbling crepitations synchronous with the heartbeat. He said that the diagnosis was greatly facilitated by the appearance of subcutaneous emphysema. In 1918 Rees and Hughes,[8] Smith,[9] and Munden[10] pointed out the diagnostic significance of these sounds. Smith termed the sound "pericardial knock" which he heard over the precordium in penetrating wounds of the chest. In 1937 Hamman[11] called attention to the clinical picture of six cases which had spontaneous air occurring over the mediastinum. In the same year Scott[12] reported two cases and thought the accompanying pain was due to angina pectoris. Additional cases have been recognized by McGuire and Bean,[13] Morey and Sosman,[14] Wolfe,[15] Matthews,[16] Pinckney,[17] Caldwell,[18] Styron,[19] Miller,[20] Murphy and Zeis,[21] Griffin,[22] Lintz,[23] Greene,[24] and Adcock.[25] In 1944 Miller[26] added four more cases, two of which demonstrated this condition and an associated spontaneous pneumothorax.

Graham, Singer, and Ballon[27] observed mediastinal emphysema after pulmonary lobectomy. Sercer and Peicic[28] said it occurred during pneumothorax. Parfitt and Crombie[29] reported the same condition when the lung was injured. Alexander[30] reported a case of tuberculosis which developed interstitial, mediastinal, and subcutaneous emphysema after spontaneous collapse of the involved lung. Pneumothorax had been instituted, but the collapse was not due to trauma. Jehn and Nissen,[31] and Banyai and Jurgens[32] have reported mediastinal emphysema following pneumoperitoneum. Since the emphysema occurred following injection of air by the subphrenic route and did not occur when air was given by the subumbilical route, the pneumomediastinum was due to misplaced air dissecting upward under the basal parietal pleura.

Graebner[33] reported three cases of pneumomediastinum and two of pneumopericardium. In one case of pneumopericardium tracheotomy had been performed twenty-four hours previously. In the other case pneumopericardium cutaneous emphysema. Interstitial emphysema was present, no doubt, prior to the bronchoscopy and may have been responsible for the most uncontrollable cough ever witnessed in a patient by the author.

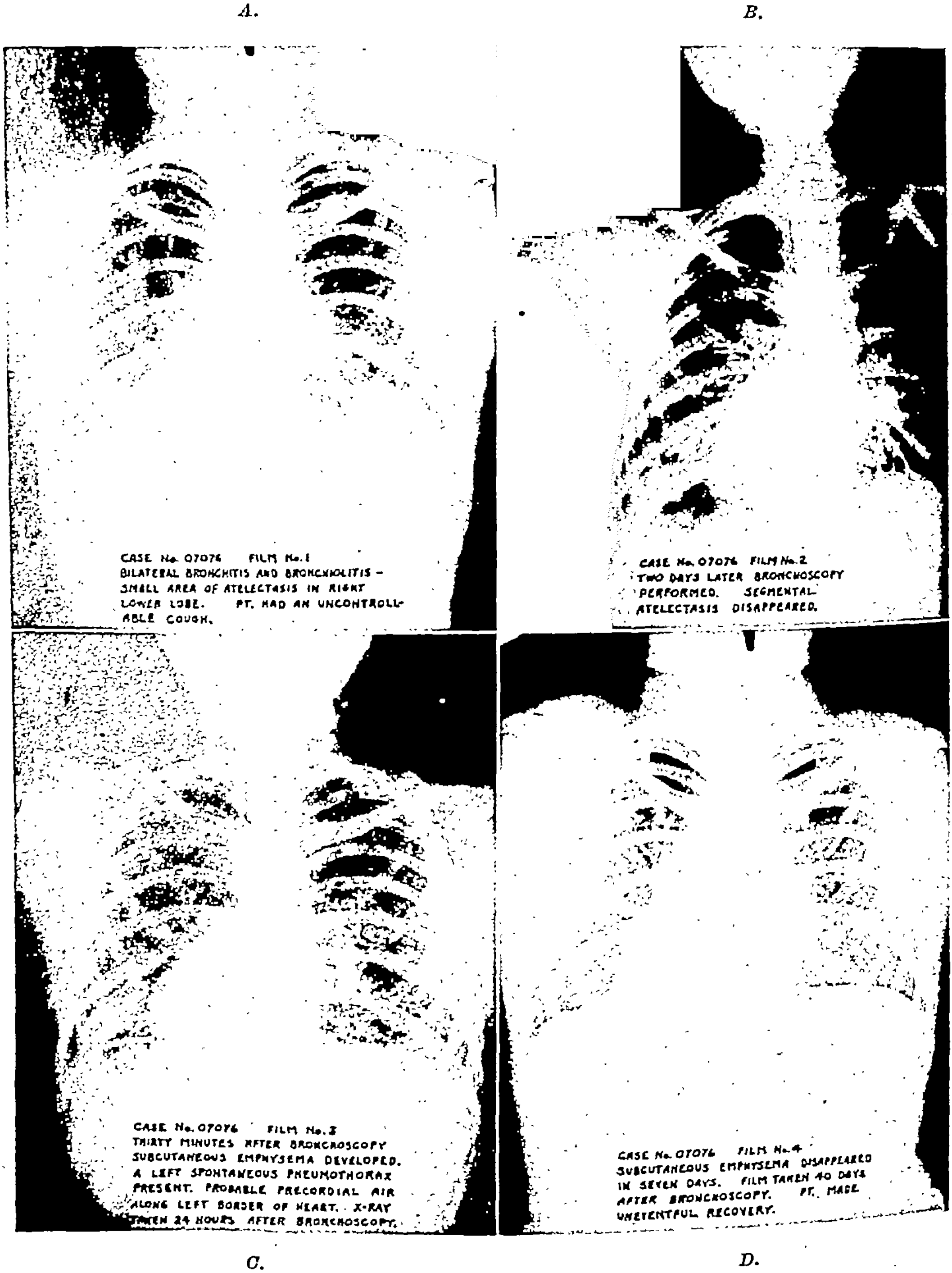

A.
B.
CASE No. 07076 FILM No. 1
BILATERAL BRONCHITIS AND BRONCHIOLITIS –
SMALL AREA OF ATELECTASIS IN RIGHT
LOWER LOBE. PT. HAD AN UNCONTROLL-
ABLE COUGH.
CASE No. 07076 FILM No. 2
TWO DAYS LATER BRONCHOSCOPY
PERFORMED. SEGMENTAL
ATELECTASIS DISAPPEARED.
CASE No. 07076 FILM No. 3
THIRTY MINUTES AFTER BRONCHOSCOPY
SUBCUTANEOUS EMPHYSEMA DEVELOPED.
A LEFT SPONTANEOUS PNEUMOTHORAX
PRESENT. PROBABLE PRECORDIAL AIR
ALONG LEFT BORDER OF HEART. X-RAY
TAKEN 24 HOURS AFTER BRONCHOSCOPY.
CASE No. 07076 FILM No. 4
SUBCUTANEOUS EMPHYSEMA DISAPPEARED
IN SEVEN DAYS. FILM TAKEN 40 DAYS
AFTER BRONCHOSCOPY. PT. MADE
UNEVENTFUL RECOVERY.
C.
D.

Fig. 2.—*A*, bilateral bronchitis and bronchiolitis—segmental atelectasis in the right lower lobe. *B*, Bronchogram shows disappearance of area of segmental atelectasis. *C*, Twenty-four hours after bronchoscopy—subcutaneous emphysema and spontaneous pneumothorax on the left. *D*, Forty days after occurrence of interstitial mediastinal subcutaneous emphysema and spontaneous pneumothorax.

heart and subsequent circulatory embarrassment. In animal experiments Ballon and Francis[2] noted that when mediastinal emphysema was marked, subcutaneous emphysema was slight, and vice versa. Most clinicians point out that the pathognomonic sign of mediastinal emphysema is the crunching, crackling, popping sign which is synchronous with the heartbeat.

In this report two cases are presented. Case 1 (Fig. 1, *A*), a boy, aged 4 years, was admitted without x-ray evidence of intrathoracic air, but with a marked subcutaneous emphysema. Fig. 1, *B* shows an x-ray view of the same patient ten days after symptoms had subsided; no air was present. In the second case, a boy 13 years of age (Fig. 2, *A*), the radiograph shows a bilateral bronchitis and bronchiolitis. A small area of atelectasis is present in the right lower lobe. Fig. 2, *B* shows a radiograph immediately after bronchoscopy. The segmental atelectasis in the lower lobe had disappeared. Fig. 2, *C* shows a radiograph taken twenty-four hours after bronchoscopy. Thirty minutes after bronchoscopy subcutaneous emphysema was evident. A left spontaneous pneumothorax remained twenty-four days after the occurrence of mediastinal emphysema. The patient made an uneventful recovery and the uncontrollable cough disappeared.

CASE 1 (Fig. 1, *A* and *B*).—The patient, a boy aged 4 years, was admitted with a generalized subcutaneous emphysema of twenty-four hours' duration. He complained of tightness around the neck and some shortness of breath. Temperature was 100.2° F., pulse 120. X-ray picture demonstrated subcutaneous emphysema, but no spontaneous pneumothorax. Heart sounds were not accompanied by any crunching sounds, since the air had disappeared into the subcutaneous tissues, as evidenced by x-ray. The cause of the initial interstitial and mediastinal emphysema was due to excessive coughing while the patient was convalescing from an attack of measles. After five days of hospitalization, the patient was comfortable and made an uneventful recovery.

CASE 2 (Fig. 2, *A*, *B*, *C*, and *D*).—The patient, aged 13 years, white, male, overweight, was admitted to the hospital with a history of a pulmonary illness of seven weeks' duration. Temperature was 102° F., pulse 110, respiration 23. He had violent coughing attacks and was raising a moderate quantity of sputum. The sputum was negative for any specific organism, but a few gram-negative, rod-shaped diplococci were observed. The white blood cell count was 11,500. A diagnosis of bilateral bronchiolitis was made. After the bronchoscopy a course of sulfonamide and penicillin was administered. In two weeks the patient was discharged from the hospital.

Ten days after discharge the patient re-entered the hospital, with a temperature of 101° F. Paroxysmal attacks of coughing persisted. A small area of atelectasis was observed in the right lower lobe. It was impossible to control the cough. The second bronchoscopy was unventful, and a bronchogram showed the atelectatic area had disappeared. Thirty minutes after bronchoscopy the patient experienced dyspnea. He complained of choking and of not being able to breathe. The subcutaneous tissues of the chest, neck, and entire face were distended with air. The eyelids puffed out and interfered with vision. A crunching sound was audible over the mediastinum. He was placed in an oxygen tent. A Levine tube was inserted into the esophagus for feeding, since the patient claimed he could not swallow. The pulse increased to 120, and temperature averaged 101° F. for three days. The subjective symptoms subsided in four days. Subcutaneous air disappeared in seven days. Recovery was uneventful. Bronchoscopy probably hastened the occurrence of the mediastinal and sub-

Clinically, the onset in pulmonary collapse is usually sudden. The course of idiopathic spontaneous pneumothorax is benign and afebrile, often with a transudate, but not exudate. Pain and shortness of breath make the patient realize that something has happened. Pain is exaggerated during inspiration and may increase as the intrathoracic pressure increases. If the valvelike opening in the pleura closes, the pressure may become neutralized and symptoms may ultimately disappear, even without re-expansion of the lung. The duration of a tension pneumothorax is proportional to the length of time it takes the opening in the visceral pleura to close. In this series, one patient had a pneumothorax for eight months after the tension pneumothorax had run its brief course. The continuation of the pneumothorax was probably due to leakage of air into the thoracic cavity intermittently through a valve-like opening in the lung. This is the cause of a prolonged pneumothorax.

Several authors [10,50,56,57] report a few cases in which lungs have remained collapsed for as long as seven and one-half years and ultimately have re-expanded. In other cases, re-expansion has failed to occur and the patients have had varying degrees of disability for years. Bassel[58] has reported the case of a patient who probably had an unexpanded lung for seventeen years, and who underwent a successful major surgical procedure (gastroenterostomy).

The course of pathologic spontaneous pneumothorax is usually severe. In those patients who have pathologic spontaneous pneumothorax, cyanosis and shock often occur, especially if there is a mediastinal shift, pulmonary hemorrhage, or tension pneumothorax. Spontaneous pneumothorax due to trauma, such as fractured ribs, stab and gunshot wounds, or causes due to sudden pressure changes occur frequently. Hemothorax is often supplementary, and treatment for hemorrhage, as well as shock, is necessary. Holter and Horwitz[59] reported a case of spontaneous pneumothorax in an airplane. Wilcox and Foster-Carter[60] (1937) cited a case in which an air pilot died during the third attack.

In this study twelve cases are reported which had spontaneous pathologic pneumothorax. Four patients who had bilateral tuberculosis died. Of the remaining eight, five had pulmonary tuberculosis, and two bronchitis. One had silicosis, due to fluorspar dust, and later died. One patient with tuberculosis had a thoracoplasty and died with a spontaneous pneumothorax in the opposite lung one week after the operation.

Spontaneous idiopathic pneumothorax may occur in either sex at any age. Wilson[61] stated that it more frequently appears in male adults. In this series of twenty patients, twelve were male and eight were female. Fifteen occurred on the right side and five on the left side. None of these cases were bilateral, or alternating. In the twenty cases of idiopathic spontaneous pneumothorax, the average duration was three months, except one case which had eight recurrences over a period of five years. One patient had two occurrences in one month; one, four in one month; one, six in six months; and one, five in two months. Locke[62] reported one patient who had a recurrence of spontaneous pneumothorax eighteen times. Eleven patients had air removed at periodic

SPONTANEOUS PNEUMOTHORAX

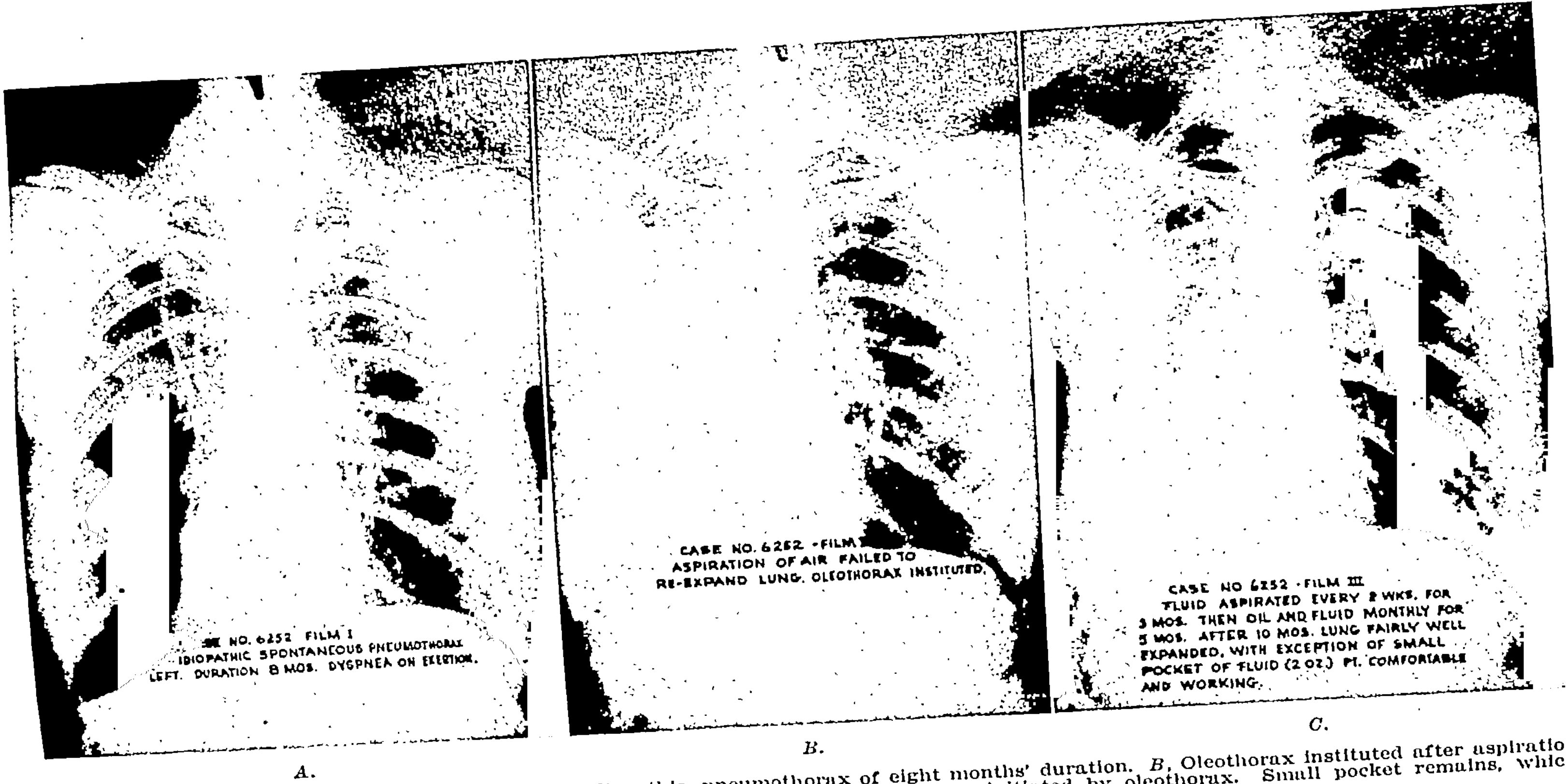
Laennec[35] in 1819 discussed spontaneous pneumothorax, nontuberculous pneumothorax, and double pneumothorax, which is today diagnosed as bilateral simultaneous pneumothorax. In 1887 Hall[36] reported the first series of spontaneous pneumothorax in the healthy individual. Riesman and Fussel[37] (1902) and Emerson[38] (1903) were the first to report nontuberculous spontaneous pneumothorax in this country. At this time it was thought the etiologic factor was tuberculosis. Our present concept concedes that the most common etiologic factors are emphysematous blebs in the pleura. Gordon[39] described five cases in which, after re-expansion, he could delineate the bullae. Kirschner[40] reported twenty cases of spontaneous pneumothorax, and in one patient, who died of acute cardiac failure, he found a rupture of a pleural bleb.

In 1931 Kjaergaard[41] wrote extensively on spontaneous pneumothorax in the apparently healthy. In the same year McMahon[42] reported a case of spontaneous bilateral pneumothorax. Glickman and Schlomovitz[43] reported a case of simultaneous bilateral pneumothorax complicating pneumoconiosis, which brought the number of bilateral simultaneous pneumothorax cases to eighty-two. Gaetan[44] reported a case of simultaneous bilateral pneumothorax due to tuberculosis in 1942. Superimposed spontaneous pneumothorax occurs more frequently than is generally believed, since it happens in many patients receiving therapeutic treatment for tuberculosis. McCloskey[45] reported on a series of 1,131 cases of induced pneumothorax. These cases had 52,835 refills over a period of six years, and this condition was noted 161 times, or 14.2 per cent.

Charr[46] cited eleven cases of spontaneous pneumothorax; Schomer and Ehrlick[47] (1935) six cases; Ehrlick and Schomer[48] (1938) seven cases; Hedgpeth and co-workers[49] (1944) twenty cases; Babington[50] (1944) forty-four cases, including thirteen of his own; Hadley[51] (1941) five cases. Griffin[52] (1942) wrote that the incidence of spontaneous idiopathic pneumothorax is one case per thousand in male students. Englehardt and Derbes[53] reported two cases of spontaneous pneumothorax caused by bronchial asthma. The thinning of the alveoli wall was verified at autopsy.

The average case of idiopathic spontaneous pneumothorax demands few therapeutic suggestions, but spontaneous ruptures caused by pulmonary disease require urgent and immediate treatment. Tuberculosis is the etiologic factor involved in the majority of cases of pathologic spontaneous pneumothorax. Chronic emphysema, interstitial and mediastinal emphysema, pneumoconiosis, bronchopneumonia, bronchitis, asthma, congenital cysts, and tumors are other etiologic factors.

Mild cases of idiopathic spontaneous pneumothorax are diagnosed pleurisy, myositis, or intercostal neuralgia, especially if there is no recurrence. Oechsli and Skillen[54] reported a case of spontaneous pneumothorax with predominantly abdominal symptoms of pain, nausea, and vomiting due to downward retraction of the diaphragm. Joress[55] reported two cases with similar symptoms.

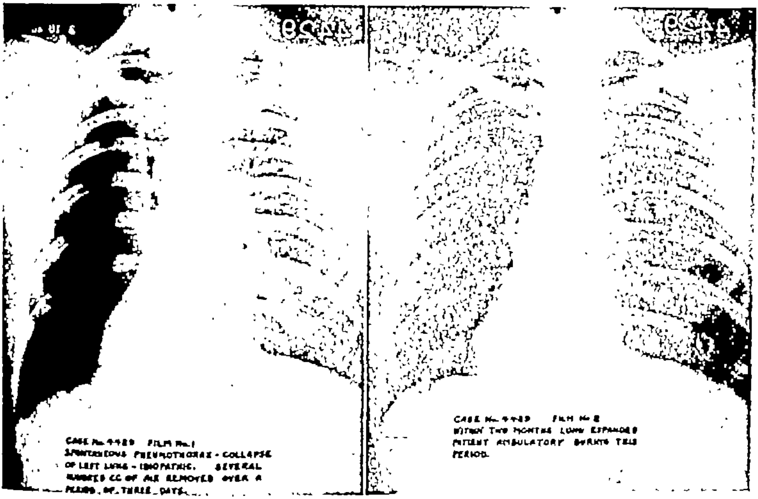

NO. 6252 FILM I
IDIOPATHIC SPONTANEOUS PNEUMOTHORAX
LEFT. DURATION 8 MOS. DYSPNEA ON EXERTION.
CASE NO. 6252 - FILM
ASPIRATION OF AIR FAILED TO
RE-EXPAND LUNG. OLEOTHORAX INSTITUTED.
CASE NO 6252 - FILM III
FLUID ASPIRATED EVERY 2 WKS. FOR
3 MOS. THEN OIL AND FLUID MONTHLY FOR
5 MOS. AFTER 10 MOS. LUNG FAIRLY WELL
EXPANDED, WITH EXCEPTION OF SMALL
POCKET OF FLUID (2 OZ.) PT. COMFORTABLE
AND WORKING.

A. *B.* *C.*

Fig. 4.—*A*, Radiograph shows spontaneous, idiopathic pneumothorax of eight months' duration. *B*, Oleothorax instituted after aspiration of air failed to re-expand lung. *C*, Radiograph shows obliterative pleuritis which was initiated by oleothorax. Small pocket remains, which contained 2 ounces of fluid.

intervals for comfort, three were treated with an irritant oil,[63] and four received no treatment. All recovered. Fig. 3, *A* is a radiograph showing spontaneous collapse of idiopathic etiology. Fig. 3, *B* shows a radiograph of the same patient two months later. No treatment was indicated.

Tyson, Crandall, and Hanover[64] (1941) reported on the surgical treatment of one case of recurring idiopathic spontaneous pneumothorax due to a ruptured bleb. He placed a purse-string suture at the base of the cyst, drew it tightly, and removed the bleb.


CASE No. [illegible] FILM No. 1
SPONTANEOUS PNEUMOTHORAX - COLLAPSE OF LEFT LUNG - IDIOPATHIC. SEVERAL HUNDRED CC OF AIR REMOVED OVER A PERIOD OF THREE DAYS.
CASE No. [illegible] FILM No 2
WITHIN TWO MONTHS LUNG EXPANDED PATIENT AMBULATORY DURING THIS PERIOD.

A. *B*.

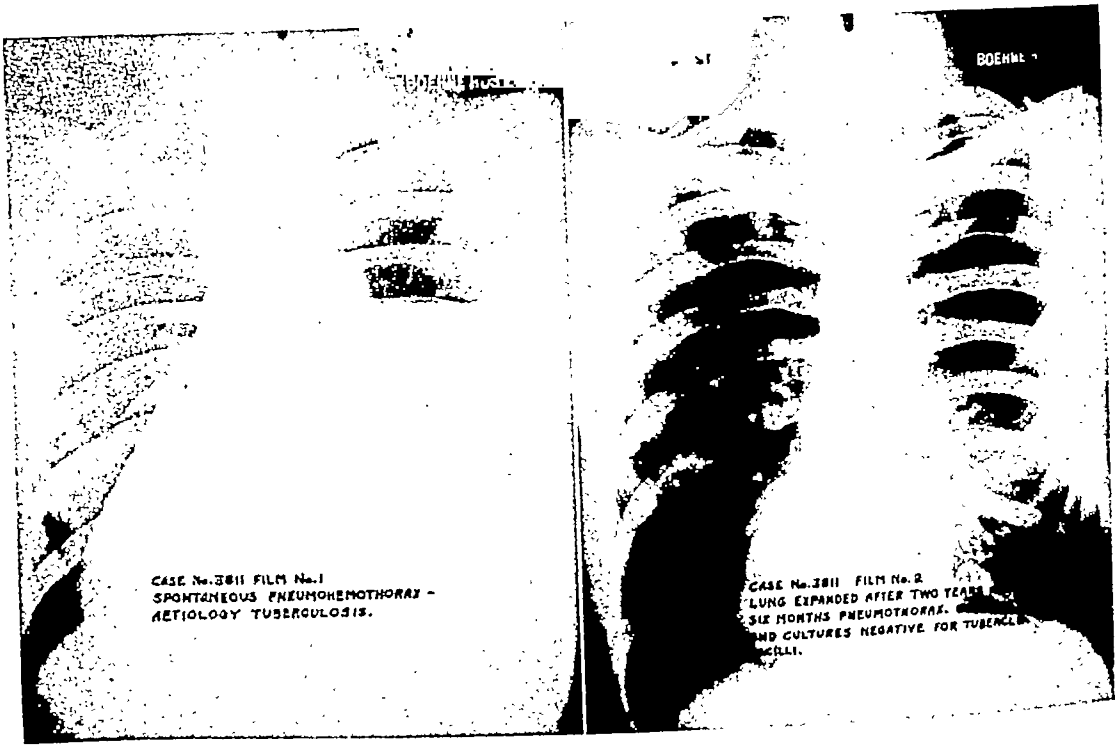
Fig. 3.—*A*, Radiograph shows idiopathic spontaneous pneumothorax. *B*, Re-expansion of lung two months after occurrence of idiopathic spontaneous pneumothorax.

Hoyer and Clagett[65] were the first to perform a lobectomy for chronic spontaneous pneumothorax. They removed the middle lobe of the right lung because of multiple emphysematous bullae.

Pulmonary re-expansion has been obtained in a number of cases by the introduction of irritant substances into the pleural cavity for the purpose of producing obliterative pleuritis (Kjaergaard,[66] Harvey,[67] Hennel and Steinberg,[68] and Morlock[69]).

Chandler[70] (1937) used Gomenol in olive oil to produce obliterative pleurisy. He used only 25 c.c. of 20 per cent Gomenol and olive oil to create an exudative reaction, which he thought aided in the re-expansion of the lung. He also used 50 per cent dextrose to create the same condition.

Without the knowledge of Chandler's work, I used peanut oil effectively. However, unlike Chandler, a larger quantity of an irritant and not a bland in cases reported by Coyon,[73] Hanot,[74] Montague,[75] Mainini,[76] Lancelin and Bideau,[77] Churnton,[78] Korol,[79] and Heise and Krause.[80] In the same year (1936) Korol[79] reviewed thirty-four cases of hemorrhagic pleurisy which occurred since 1900. Prior to 1900 verification by x-ray was not available. Korol[79] reported thirty cases of hemorrhage which occurred during artificial pneumothorax. In a series of 50,000 pneumothoraces, I have not seen a single case of hemorrhage in the pleural space which happened during the course of treatment. A hemorrhagic exudate seldom occurs if the lung is properly re-expanded. It does occur when an oleothorax is allowed to re-expand. Fluid which forms during re-expansion may become hemorrhagic. This may be due to the presence of granulation tissue, but more than likely it is due to the high negative pressure of some aspirations. It has been called *exudate ex vacuo.*



A. *B.*

Fig. 5.—*A*, Spontaneous pneumohemothorax. *B*, Radiograph shows re-expansion of lung in tuberculous pneumohemothorax after two and one-half years of pneumothorax.

Almeyda[81] cited a case of spontaneous hemothorax, and stated that the blood which settles on the diaphragm lacks fibrin. Birch[82] (1936) and Beatty[83] (1939) reported cases of hemothorax due to rupture of an alveolar cyst arising from scarred tuberculous foci. Davidson, Oxfd, and Simpson[84] reported a case of apical bullae and the tearing of adhesion which caused a hemorrhage. Perry and Camb[85] (1938) reviewed nineteen cases in the literature and reported two cases of their own. No evidence of tuberculosis was found in eight of the patients who died. In four autopsies of their cases a ruptured vascular adhesoil was used, endeavoring at all times to keep the entire thoracic space filled with oil or fluid. This insures a pleuritis over the entire lung surface. After the oil remains for two to four weeks, it is gradually withdrawn at weekly intervals, along with fluid, to aid in lung re-expansion. With this procedure and the obliterative pleuritis which is created by the irritant oil, the lung is re-expanded gradually. The pleuritis seals over the opening in the pleura. One case reported (Fig. 4, *A*) had a spontaneous pneumothorax of eight months' duration. Oleothorax was instituted (Fig. 4, *B*) and carried for eight months before considerable re-expansion of the lung occurred (Fig. 4, *C*). A pulmonary fistula which is too large for oleothorax must be treated by the constant removal of air with suction. In these cases, a suction pump[71] can be attached to a water faucet and connected by tube to a needle in the chest wall. Periodic or continuous suction is applied. One patient with tuberculosis had this treatment twenty-four hours a day for one week, at the end of which time the exudate sealed the visceral fistula. Thoracoplasty and a modified Schede operation were employed in closing the emphysema cavity.

SPONTANEOUS HEMOPNEUMOTHORAX

Nontraumatic spontaneous hemopneumothorax occurs in the same manner as spontaneous pneumothorax, except for the presence of hemorrhage. In fact, a spontaneous collapse by air probably precedes the hemorrhage. Often the air is absorbed when the hemothorax is discovered.

The quantity of blood in hemopneumothorax depends on the time it takes the collapsed lung to retract the bleeding vessel. Hemorrhage often occurs after the visceral pleura ruptures, and the bleeding vessel may not necessarily be in the opening of the pleura but in a torn vascular adhesion. Blood should not be left in the pleural cavity because the fibrin may later calcify. Irritation of the diaphragm caused by the blood and shifting of the mediastinum often bring about abdominal symptoms which require a differential diagnosis from appendicitis, perforated ulcer, or gall bladder disease. Not infrequently the kidney is investigated for the cause of the abdominal pain.

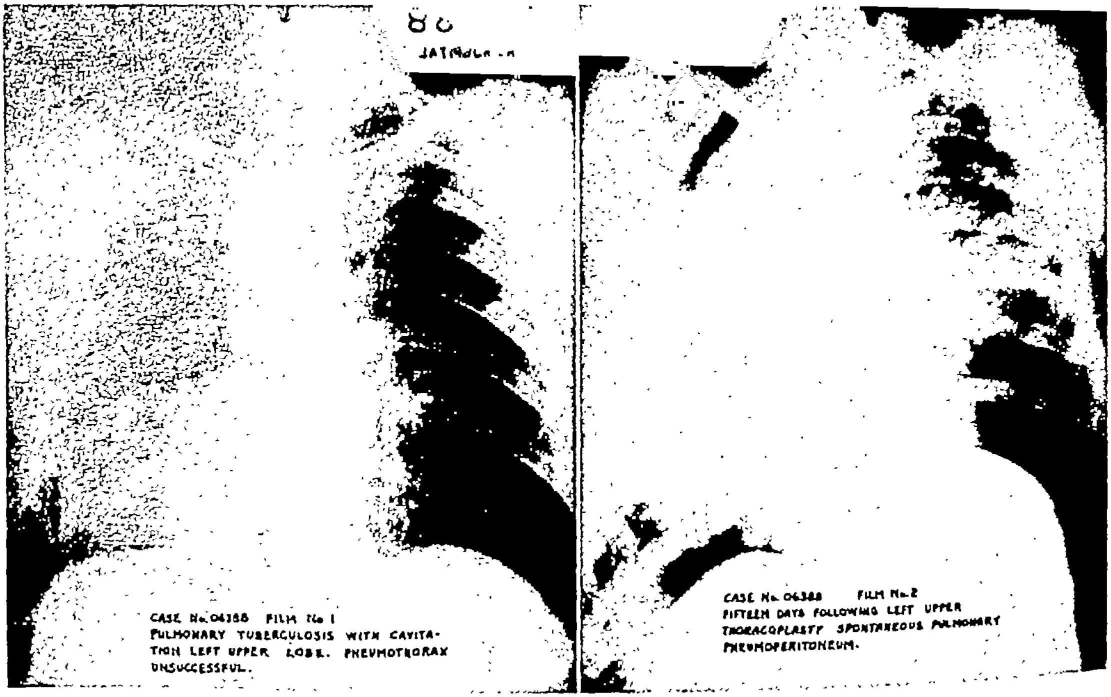
Clinically, the symptoms of hemopneumothorax consist of sudden onset of pain and dyspnea. Some improvement takes place until sign of excessive internal hemorrhage occurs. Abdominal symptoms may mask the lung collapse until extreme dyspnea suggests a roentgenogram of the chest. Physical signs of dullness and diminished breath sounds can be overlooked. The treatment consists of blood transfusion, with aspiration of the blood from the pleural cavity. Pneumothorax may be indicated. If compression by air does not stop the hemorrhage, an exploratory thoracotomy is advisable.

Hemopneumothorax not associated with trauma, heart disease, tumor, or pulmonary infarction is quite rare. In 1936 Jones and Gilbert[72] reviewed the literature on spontaneous hemopneumothorax and reported twenty-three cases from other clinical reports and one case of their own. Of the twenty-four cases, only one case had tuberculosis as a definite etiology. One patient reported in this series had tuberculosis. Tuberculosis was found in the hemorrhagic fluid

SPONTANEOUS PULMONARY PNEUMOPERITONEUM

Spontaneous pulmonary pneumoperitoneum is an extremely rare condition. Indirect pneumoperitoneum, due to the flow of air from the pleural space into the abdominal cavity, is not too frequent. Indirect pneumoperitoneum has occurred following pneumothorax and during anesthesia, where excessive pressure has been the etiologic factor. Elrick,[86] Fishberg,[87] Stephani, Stephani, and Desboeuf,[88] and Banyai[89] have reported cases following pneumothorax. Eisen[90] in 1938 reported a case of spontaneous pneumothorax, mediastinal emphysema, and pneumoperitoneum which occurred during a closed ether anesthesia.

In 1944 Sidel and Wolbarsht[91] reported a case of indirect pneumoperitoneum, probably caused by a suspected temporary fistula which extended through the diaphragm into the abdominal cavity. This patient had pneumonia in the lower lobe of the left lung. The roentgenogram showed increased density in this area and a layer of air below the diaphragm. The patient recovered, and the air disappeared within two months.


CASE No. 06388 FILM No. 1
PULMONARY TUBERCULOSIS WITH CAVITATION LEFT UPPER LOBE. PNEUMOTHORAX UNSUCCESSFUL.
CASE No. 06388 FILM No. 2
FIFTEEN DAYS FOLLOWING LEFT UPPER THORACOPLASTY SPONTANEOUS PULMONARY PNEUMOPERITONEUM.

A. *B.*

Fig. 7.—*A*, Pulmonary tuberculosis with cavitation of left upper lobe. *B*, Spontaneous pulmonary pneumoperitoneum. Pocket of air at left apex is between scapula and chest wall.

The case herein reported (Fig. 7, *A*) was a patient with pulmonary tuberculosis, who had a left thoracoplasty (one stage, three rib section.) He recovered from the operation, but had discomfort from abdominal distention. On the fifteenth day the abdomen became markedly distended. An x-ray picture (Fig. 7, *B*) revealed pneumoperitoneum. This air was removed and patient was relieved. One week later he died of coronary occlusion. Autopsy showed ion was found, and in the other no satisfactory explanation was found. Two cases of hemothorax are reported herein. Case 1 (Fig. 5, *A*) was tuberculous. Fig. 5, *B* shows a radiograph of the same patient after two and one-half years of pneumothorax treatment. Case 2 (Fig. 6, *A*) had a spontaneous hemothorax of nonspecific origin. Fig. 6, *B* is a film of the same patient forty-six days after blood had been absorbed and lung re-expanded.

CASE 1.—The patient, aged 24 years, a bank clerk, experienced a sudden pain in the right chest. Three hours after this attack he fainted. This was followed by considerable pain for several hours. He continued to work the next day and visited a physician, who taped the chest for pleurisy. Two days later x-ray view showed the right side of the chest two-thirds filled with fluid and one-third air. The patient was admitted to the hospital. A thoracentesis revealed the fluid to be blood. Guinea pig inoculation was positive for tubercle bacilli. The blood was gradually removed and replaced with air. The blood was totally removed in one month's time. Pneumothorax was continued for two years and the lung permitted to re-expand. Culture and gastric analyses were negative for tubercle bacilli.

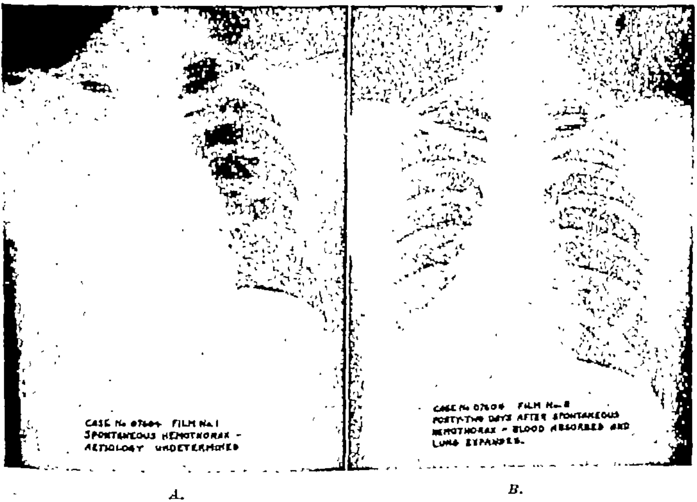


Fig. 6.—*A*, Spontaneous hemothorax. *B*, Forty-two days after hemorrhage. Lung re-expanded.

CASE 2.—The patient, aged 48 years, a housewife, developed sudden pain in the abdomen, and cramps and nausea. Complaints were referred to the abdomen, which caused one to suspect some involvement in the left kidney and abdominal region. Forty-eight hours later the patient complained of shortness of breath, which led to an x-ray examination. This revealed increased density in the left pleural space, and a partially collapsed lung. Marked secondary anemia was present. Thoracentesis revealed pure blood. No bacteriologic studies were made. Several hundred cubic centimeters of blood were removed, which gave the patient immediate relief. The remainder of the blood was absorbed. Three transfusions restored the blood picture to normal and the patient made an uneventful recovery.

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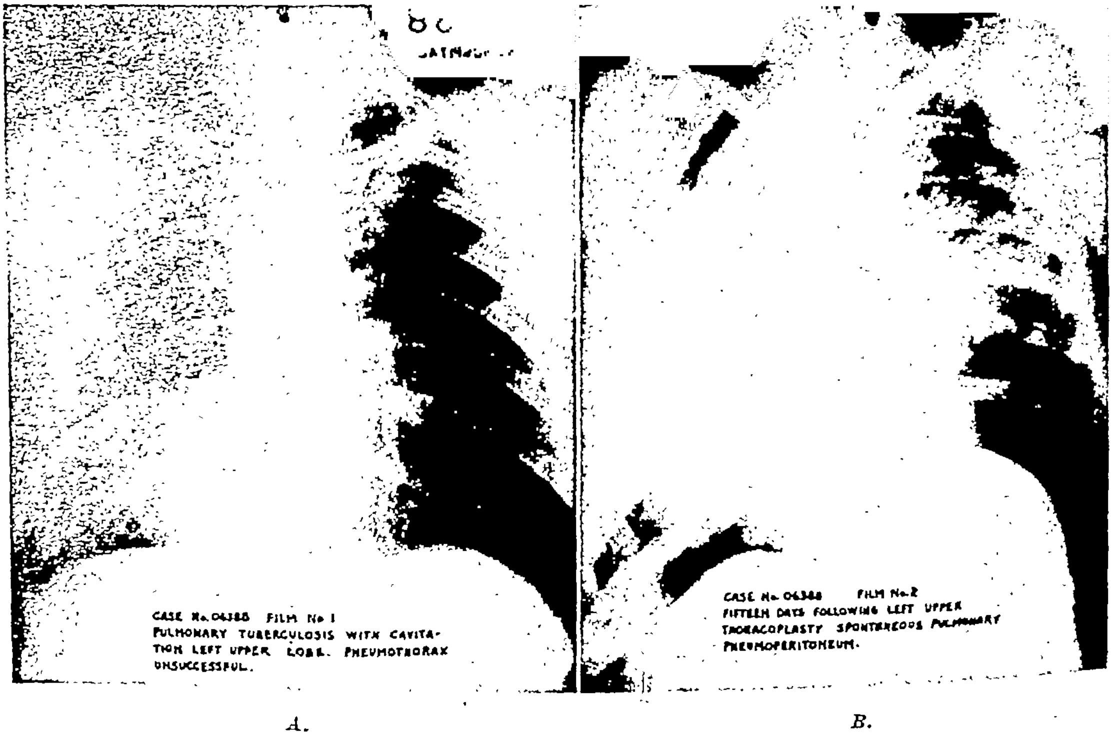
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The pneumoperitoneum in this case and the one of Sidel and Wolbarsht[91] was evidently caused by a direct connection from the lung through the diaphragm into the abdominal cavity. These cases demonstrate that a spontaneous pulmonary pneumoperitoneum does occur when a pathologic process creates an opening through the diaphragm. In the case reported here the fistula was valvelike, if the early abdominal distention was due to extraneous air and not flatus. This postoperative pneumoperitoneum (Fig. 7, *B*) occurred because of a pathologic process, even though the operation may have hastened the opening of a potential fistula.

CASE 1.—The patient, aged 61 years, a banker, white man, had been ill for one year with pulmonary tuberculosis. X-ray showed infiltration in the left lung with cavitation in the apex and a moderate amount of infiltration and fibrosis in the right upper lobe. An unsuccessful pneumothorax on the left side had been discontinued. He was referred for thoracoplasty. On Feb. 5, 1945, a posterior left thoracoplasty was performed. Recovery was uneventful, except for some distention of the abdomen, until the fifteenth postoperative day. Temperature elevated to 104° F., pulse rate 120, respiration 24. A diagnosis of pneumoperitoneum was made, and the patient was given relief by aspiration of air. He died of coronary occlusion one week later.

Autopsy Report.—The aorta was enlarged and atheromatous. The right ventricle was moderately dilated, and the wall contained two areas of healed infarction. The anterior coronary was calcified throughout, and part of the circumflex coronary was occluded. Considerable fibrosis and numerous healed tubercles were present in both lobes of the left lung. The cavity was collapsed. The lower lobe was adherent to the diaphragm, except in the anterior third. A few ounces of thick exudate were found in the costophrenic space. The omentum was plastered to the inferior surface opposite the dense adhesions on the pleural surface. An attempt was made to locate the fistula, but no definite opening could be demonstrated. The right lung was fibrotic and contained a few healed tubercles. The pleurae were adherent, except where a small quantity of fluid existed in the left costophrenic angle. There was no break in the peritoneum at the hiatus for the esophagus and aorta. The viscera were intact. The large bowel was distended markedly. The middle third of the transverse colon was adherent to the cecum.

SPONTANEOUS ATELECTATIC COLLAPSE

Spontaneous lung collapse caused by the presence of extraneous air is to be differentitated from the airless lung present in acquired atelectatic collapse. Pinner[92] believed that atelectasis cannot be produced by external pressure upon the lung. He concluded that if a lung under collapse therapy or after spontaneous pneumothorax is atelectatic, there is definite indication that some such complication as endobronchial occlusion or kinking has occurred. Atelectatic collapse may be acute or chronic, involving one or more lobes or segments of different lobes of the lung. As a rule, acute segmental and chronic lobular atelectasis occurs as a complication in pulmonary disease, rather than as a definite clinical entity, like massive collapse. Acute massive collapse occurs generally after abdominal operation within forty-eight hours, less frequently within a week.

According to Lee, Ravdin, Tucker, and Pendergrass[93] Mendelsohn produced massive collapse experimentally in 1841. These investigators, Coryllos and Birnbaum,[94] and Jackson and Lee[95] demonstrated bronchial blockade by viscid secretion to be the cause of massive collapse. Graham, Singer, and Ballon[96] reviewed all previous theories advanced up to the time Lee and associates[93] proved that simple obstruction was the primary etiology. Although Pasteur's[97] theory that diaphragmatic paralysis is the cause of massive collapse has been disproved, he described the original clinical condition in 1890.

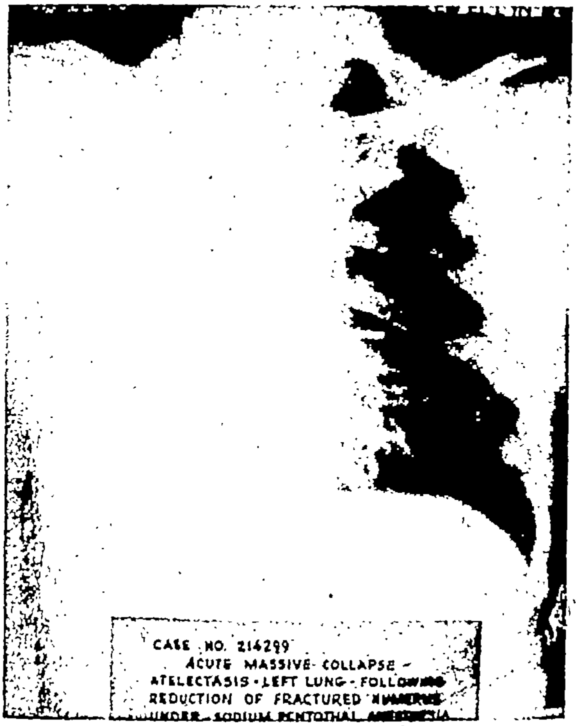
CASE NO. 214299
ACUTE MASSIVE COLLAPSE -
ATELECTASIS - LEFT LUNG - FOLLOWING
REDUCTION OF FRACTURED HUMERUS
UNDER SODIUM PENTOTHAL ANESTHESIA

Fig. 8.—Acute, massive (atelectatic) collapse. Patient recovered after four bronchoscopic aspirations. (Courtesy of Blankenhorn and Felson, Cincinnati General Hospital.)

In massive collapse the early symptom is acute pain on the affected side, as in acute pleurisy. The pain is due to tension in the potential pleural space, and shifting of the mediastinum toward the involved lung. Besides pain, other symptoms are respiratory embarrassment, fever, and expectoration of blood-streaked sputum. Cyanosis and shock may be present. Physical signs consist of diminished breath sounds over the dull area, usually without râles. The heart apez beat is displaced toward the affected lung. The opposite lung is subjected to compensatory distention, which should be called physiologic emphysema. The x-ray view verifies the diagnosis with trachea and heart displaced toward the involved lung and the diaphragm elevated. Bronchoscopy is indicated. Carbon dioxide inhalation has been used both preventively and curatively. Moorman[98] in 1930, Schindler and Gnagi[99] in 1938, and Jacobson that a fistula probably existed from the lung through the diaphragm. The fistula was not demonstrated definitely. Adhesions above the diaphragm were densely adherent, and the omentum was adherent opposite the pleural adhesions on inferior surface of the diaphragm. No retroperitoneal or viscus break was observed.

The pneumoperitoneum in this case and the one of Sidel and Wolbarsht[91] was evidently caused by a direct connection from the lung through the diaphragm into the abdominal cavity. These cases demonstrate that a spontaneous pulmonary pneumoperitoneum does occur when a pathologic process creates an opening through the diaphragm. In the case reported here the fistula was valvelike, if the early abdominal distention was due to extraneous air and not flatus. This postoperative pneumoperitoneum (Fig. 7, *B*) occurred because of a pathologic process, even though the operation may have hastened the opening of a potential fistula.

Case 1.—The patient, aged 61 years, a banker, white man, had been ill for one year with pulmonary tuberculosis. X-ray showed infiltration in the left lung with cavitation in the apex and a moderate amount of infiltration and fibrosis in the right upper lobe. An unsuccessful pneumothorax on the left side had been discontinued. He was referred for thoracoplasty. On Feb. 5, 1945, a posterior left thoracoplasty was performed. Recovery was uneventful, except for some distention of the abdomen, until the fifteenth postoperative day. Temperature elevated to 104° F., pulse rate 120, respiration 24. A diagnosis of pneumoperitoneum was made, and the patient was given relief by aspiration of air. He died of coronary occlusion one week later.

Autopsy Report.—The aorta was enlarged and atheromatous. The right ventricle was moderately dilated, and the wall contained two areas of healed infarction. The anterior coronary was calcified throughout, and part of the circumflex coronary was occluded. Considerable fibrosis and numerous healed tubercles were present in both lobes of the left lung. The cavity was collapsed. The lower lobe was adherent to the diaphragm, except in the anterior third. A few ounces of thick exudate were found in the costophrenic space. The omentum was plastered to the inferior surface opposite the dense adhesions on the pleural surface. An attempt was made to locate the fistula, but no definite opening could be demonstrated. The right lung was fibrotic and contained a few healed tubercles. The pleurae were adherent, except where a small quantity of fluid existed in the left costophrenic angle. There was no break in the peritoneum at the hiatus for the esophagus and aorta. The viscera were intact. The large bowel was distended markedly. The middle third of the transverse colon was adherent to the cecum.

SPONTANEOUS ATELECTATIC COLLAPSE

Spontaneous lung collapse caused by the presence of extraneous air is to be differentitated from the airless lung present in acquired atelectatic collapse. Pinner[92] believed that atelectasis cannot be produced by external pressure upon the lung. He concluded that if a lung under collapse therapy or after spontaneous pneumothorax is atelectatic, there is definite indication that some such complication as endobronchial occlusion or kinking has occurred. Atelectatic collapse may be acute or chronic, involving one or more lobes or segments of different lobes of the lung. As a rule, acute segmental and chronic lobular atelectasis occurs as a complication in pulmonary disease, rather than as a definite clinical entity, like massive collapse. Acute massive collapse occurs gen-

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and co-workers[100] in 1939 treated cases of massive collapse with pneumothorax. One case (Fig. 8, *A*) which was treated by bronchoscopy is reported.

CASE 1.—A white man, aged 45 years, a window cleaner, had a fracture of the right humerus, radius, and olecranon. Under Pentothal Sodium anesthesia a pin was inserted through the head of the humerus. On the second day he developed postoperative fever with sign of atelectasis (massive collapse.) This condition was treated with bronchoscopy on the third, sixth, eighth, and thirteenth day. A preoperative film was negative, except for moderate thickening of the left lower bronchi. Serial x-ray views showed gradual clearing of the entire left lung with exception of a little residual in the lower lobe.

SUMMARY

1. The continuity of interstitial, mediastinal, and subcutaneous emphysema is analyzed. Two cases are added to the few already recorded in the literature.

2. The etiology, diagnosis, and treatment of spontaneous collapse of the lung with air or blood is reviewed. Of the twenty cases of idiopathic spontaneous pneumothorax reported in this series, only three required treatment. In the three cases an irritant oil was used to initiate obliterative pleuritis. Twelve cases of spontaneous pathologic pneumothorax and two cases of nontraumatic hemothorax are reported.

3. Spontaneous pulmonary pneumoperitoneum with report of case is discussed.

4. Spontaneous lung collapse, caused by the presence of extraneous air, is differentiated from the airless lung present in acquired atelectatic (massive) collapse.

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The functions of this instrument are twofold. It is designed to obstruct completely a bronchus to an affected lobe (or lobes), and thereby prevent the transbronchial spread of purulent material. By means of suction applied through and distal to the balloon, it also serves to produce atelectasis of the portion of lung to be resected (Fig. 3).

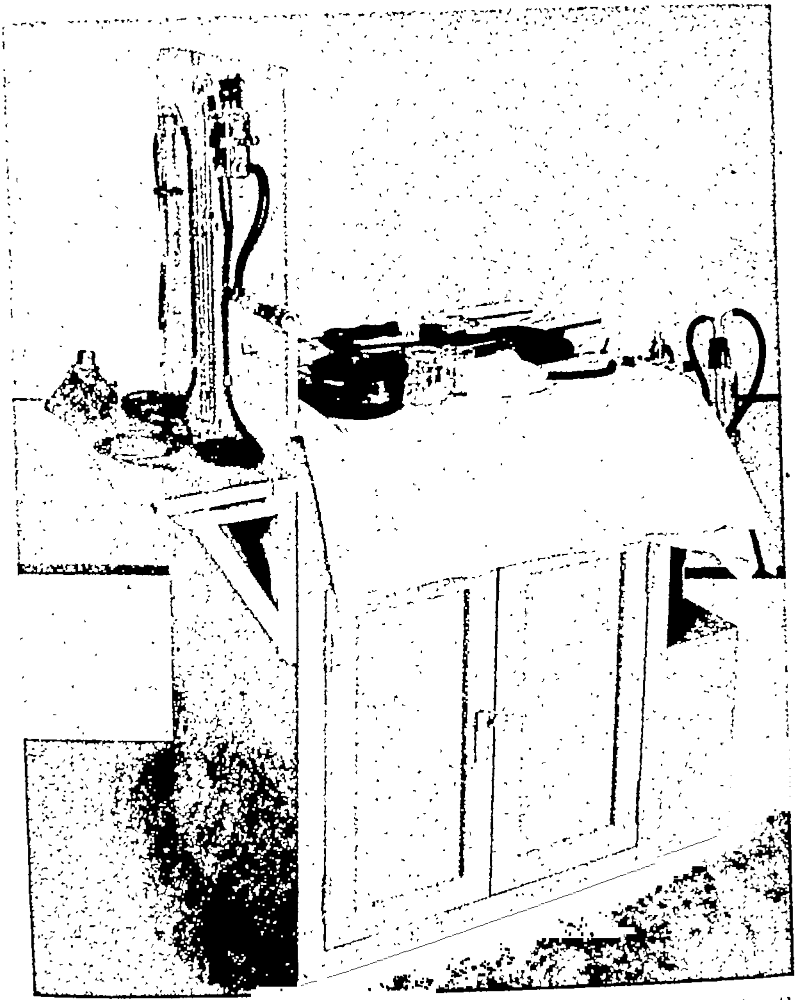

Fig. 2.—Movable table utilized as a bronchoscopy table, and as a mounting for the instrument panel.

The procedure followed in the present series of cases consists essentially of the following: Bronchoscopy is carried out on the patient following topical pontocaine anesthesia, which is applied to the trachea and bronchi as well as to the larynx and pharynx. The tracheobronchial tree is then thoroughly aspirated. Since the balloon projects a known distance of 1 cm. from the tip of the bronchoscope, the site of placement is easily localized. After this is done, pontocaine is applied directly to the site. The carrier tube containing the balloon is then inserted and the balloon released. Following inflation of the balloon to the desired pressure, the sleeve valve is turned off, disengaged, and the bronchoscope and carrier tube are removed. An endotracheal tube is then threaded over the balloon catheter and inserted, and the patient carried over into general anesthesia. The sleeve valve is recoupled as the patient is being inducted and the pressure in the balloon checked on the manometer. It is important that suction be applied distal to the balloon as soon as satisfactory anesthesia is obtained in order to prevent plugging of the aspirating tip by retained secretions. During the subsequent operation the pressure in the balloon is indicated and controlled by the mercury manometer. Following isolation of the bronchus the balloon is deflated and with-

A METHOD OF BRONCHIAL OCCLUSION FOR THE PREVENTION OF TRANSBRONCHIAL SPREAD DURING LOBECTOMY AND PNEUMONECTOMY: CLINICAL APPLICATION

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IMPROVEMENTS in the methods for control of bronchial secretions during resection for suppurative pulmonary diseases have not kept abreast of the rapid progress in the development of surgical technique. In an attempt to answer such a need, an endobronchial balloon has been devised to occlude the bronchus to an affected lobe and thereby prevent the spread of purulent secretions. A résumé of the experimental approach to the problem has been published;[1] since August, 1946, this instrument has been applied clinically in 23 cases.

At least four different methods have been used in the past and are still being used in an attempt to solve this problem. These consist of tracheobronchial aspiration by catheter, mechanical blocking or isolation of one or more lobes, various positions for the patients with dependence on gravity control of the secretions, and different types of chemotherapy. The first method, that of tracheobronchial aspiration by catheter, undoubtedly has been employed much longer than the others and, in general, is the one method on which the greatest dependence has been placed. There is no doubt but that this method has its shortcomings. Bradshaw and O'Neill[2] in 1943 reported 76 cases of pulmonary resection for bronchiectasis with the use of this technique—there were 6 deaths directly due to contralateral spread. In a recent review of 125 cases of pulmonary resection performed at this hospital during the past ten years, it has been observed that ipsilateral and contralateral spreads occurred in 27, or 21.6 per cent. Of this group there were 5 deaths, all directly attributable to the spread. As in the cases of Bradshaw and O'Neill, tracheobronchial aspiration was the method routinely used.

There have been numerous attempts to solve this problem of contralateral spread by the use of mechanical devices. In addition to the instruments of Gale and Waters,[3] Archibald,[4] Magill,[5] Nosworthy,[6] and Crafoord,[7] there has come to our attention another device originated by Halton[8] of Liverpool, England. This consists essentially of a Magill endotracheal tube through which is inserted a fine hollow steel tube on the end of which is mounted an inflatable rubber sac. The balloon tube is clamped at predetermined levels at the proximal end of the Magill tube. According to Halton, the instrument could be inserted blindly with dependence on predetermined measurements of the tracheobronchial tree, or visually alongside a bronchoscope. No cases were reported in this original paper, and no further communication concerning the instrument has been found. All of these instruments have a similar basic construction; the unit is either rigid or semirigid, and the mouth of the patient is used

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pyema, no postoperative complications have arisen due to the presence of the balloon in the main bronchus over a long period of time. In these cases, following removal of the balloon, the lung inflated very satisfactorily. There has been no interference with anesthesia at any time; on the contrary, it has been considerably aided by completely obviating tracheobronchial suction. The mechanics of operation and placement have proved quite simple. As a general rule, an average time of twenty minutes is all that is necessary from the beginning of the topical anesthesia to the completion of the placement of the balloon. Only one case has proved unsuccessful in insertion of the balloon; this was due to a combination of massive amounts of sputum and poor tracheobronchial anesthesia. The balloon has fulfilled its primary function of remaining securely in place in all except one case; in this instance there was extensive tuberculous infection of the bronchus at the site of placement of the balloon, and it was frankly suspected that the balloon would not remain in place, although it did so much longer than expected. There has been difficulty in removing the balloon in two cases at the time that the operator so desired. In one patient a sharply curved endotracheal tube prevented withdrawal of the instrument, and it had to be removed along with the balloon. In the second, the points of the holding apparatus were entirely too long and difficulty was experienced in releasing the balloon from the bronchus; this holding apparatus has since been discarded.

In this series of 23 cases, there has been one death on the operating table. This occurred in a young girl with massive unilateral tuberculosis and tuberculous bronchitis. Death occurred during hilar manipulation and shortly after removal of the balloon. There was no apparent reason for the death, and post-mortem studies could not be obtained.

In general, atelectasis has been produced satisfactorily and this has constituted a very definite advantage in allowing the surgeon considerably more operating space while maintaining expansion of the unobstructed lobe; however, in a few cases it has been only partial due to plugging of the aspirating tip by thick purulent secretions.

DISCUSSION

If the problem of preventing contralateral spread were merely one of obstructing a bronchus during the resection of an affected lobe, then this instrument should offer a satisfactory answer. As mentioned before, it fulfills all of the necessary qualifications: obstruction of the bronchus is complete; it remains safely in place despite operative manipulations; there is no interference with anesthesia; the mechanics of placement and operation are simple; and there are no harmful effects to the patient. However, through the continued use of this instrument we are becoming more cognizant of the fact that spreads may occur long before the operative procedure, may occur during preliminary bronchoscopy, and may even be confused with cases of pneumonia due directly to poor postoperative care. Consequently we are now forming a routine in operating on these patients in which the operation is postponed until late in the morning or the early part of the afternoon, postural drainage is enforced for drawn and the bronchus quickly clamped. The proximal portion of the bronchus is aspirated for any secretions which may have spilled out as the balloon was deflated. In the cases of bilateral disease, there is ample room in the endotracheal tube for passage of a suction catheter. A length of plastic tubing has been utilized which has slightly more rigidity than the usual rubber catheter.

It should be understood that this instrument is not intended to be used for an upper lobe resection; an instrument has been designed for this purpose, but thus far there has been no opportunity to test it.

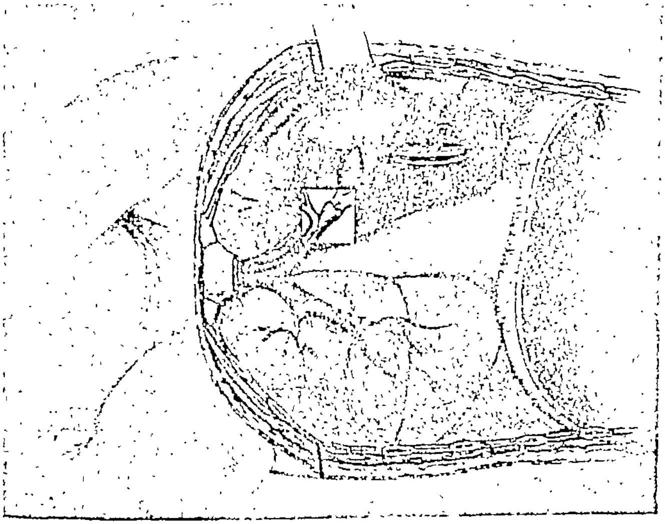

Fig. 3.—Drawing illustrating function of the instrument in obstructing the left lower lobe bronchus which communicates with a large abscess cavity.

REPORT OF CASES

During the past ten months this instrument has been used in a total of 23 cases. These consist of 10 lobectomies for bronchiectasis, 5 pneumonectomies for tuberculosis, 1 pneumonectomy and 3 thoracotomies for carcinoma, 2 pneumonectomies and 1 lobectomy for lung abscess. The remaining case was diagnosed lung abscess preoperatively, but was found to have a loculated empyema with a bronchopleural fistula.

Massive pulmonary suppuration was the primary indication for the balloon in 21 of the cases; this varied from 1 to 3 cups of sputum per day in nearly every patient. In 2 of the carinoma cases, the balloon was used solely for the production of atelectasis.

In all cases complete bronchial occlusion has occurred, evidenced either by atelectasis of the obstructed lobe, or lack of inflation under positive pressure anesthesia. There have been no obvious harmful effects in any of the patients. In the inoperable cases of carcinoma and in the patient with an em-

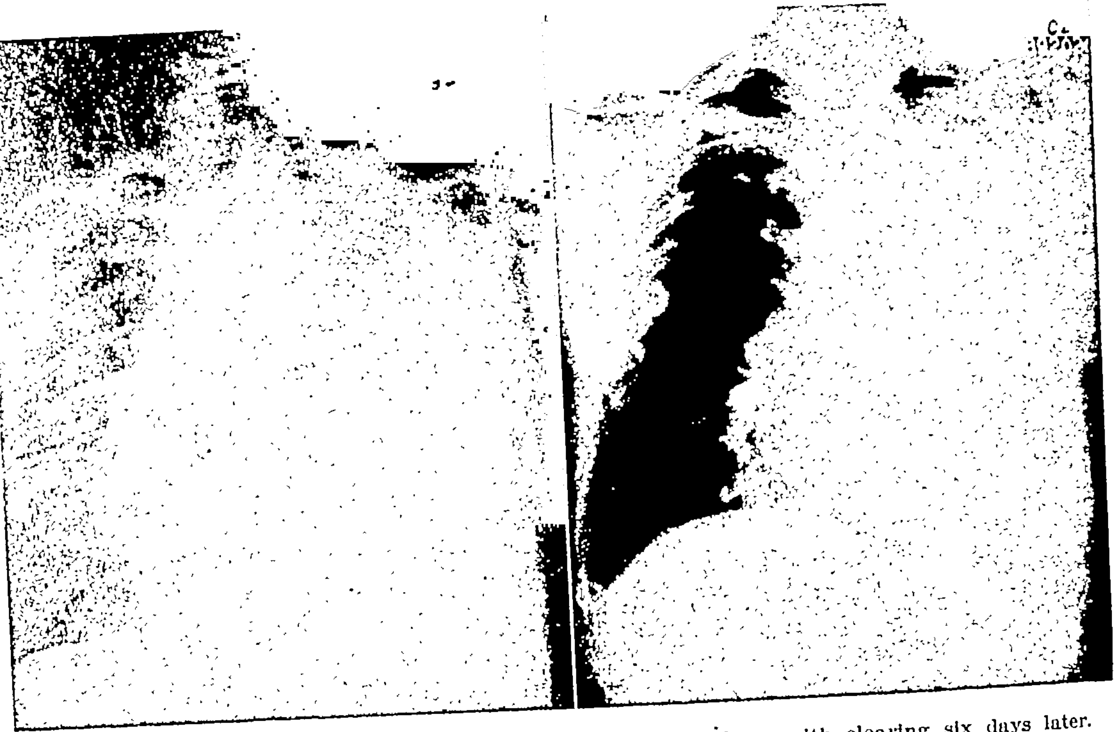

Fig. 5 (Case 2).—Very diffuse clouding of the right lung with clearing six days later. Bronchus was not clamped immediately on removing the balloon, and some spilling may have occurred.

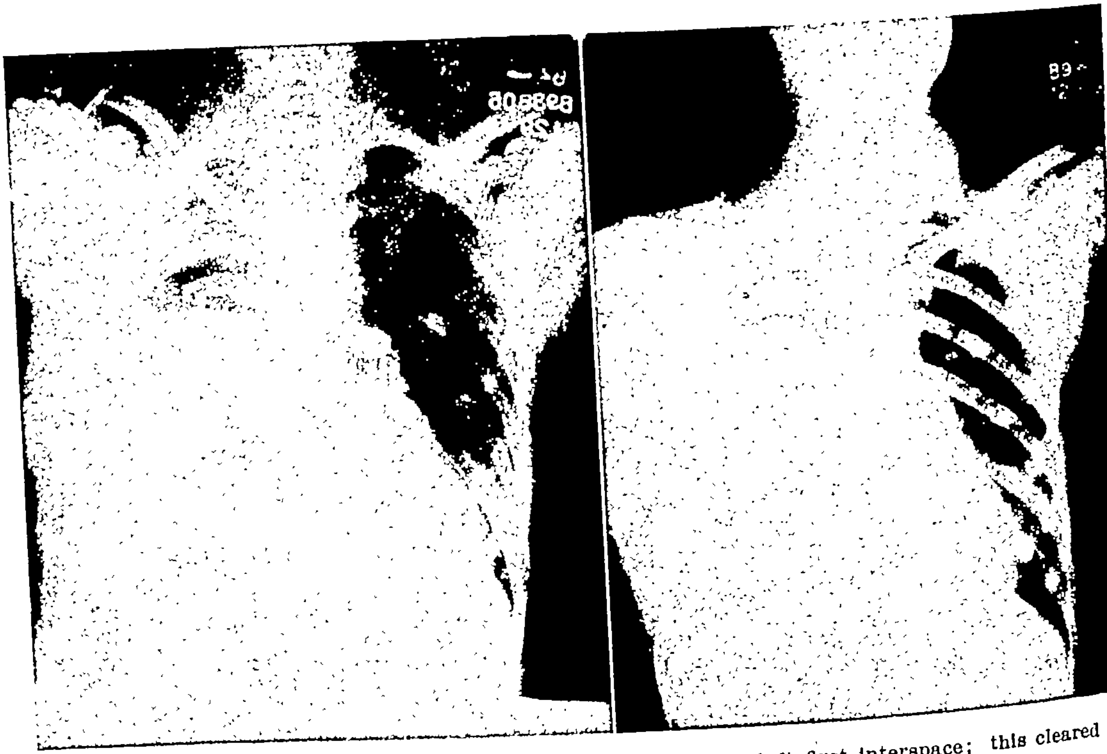

Fig. 6 (Case 3).—Very small area suggestive of spread in the left first interspace; this cleared considerably in one week's time. Bronchoscopy was difficult in this case.

several hours preoperatively, adequate anesthesia is provided for bronchoscopy, and a rigid plan including forced coughing and endotracheal suction is followed in the postoperative period. We have found that it is particularly important that adequate anesthesia be provided for bronchoscopy. There is little reason why a patient should have paroxysms of coughing during bronchoscopy when the trachea and major bronchi can be anesthetized as easily as the larynx and pharynx. In the one patient mentioned previously, in whom the balloon could not be inserted because of massive amounts of secretions, the anesthesia was quite inadequate, coughing occurred repeatedly, and there was a definite although small, postoperative contralateral spread.

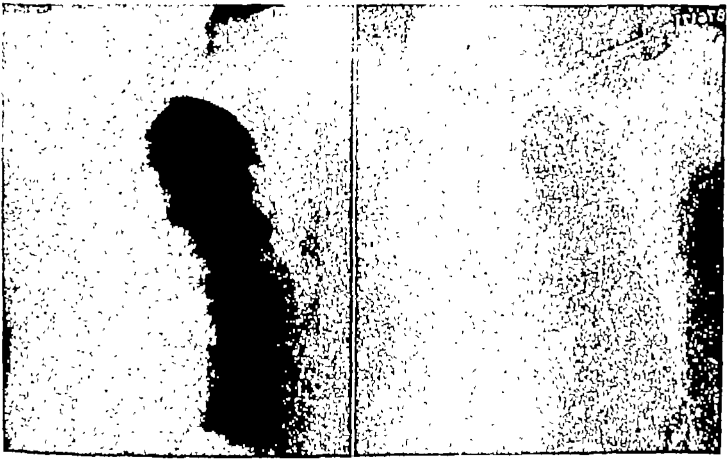

Fig. 4 (Case 1).—X-ray evidence of postoperative spread, which, twelve days later, showed beginning clearing. This spread may have occurred prior to insertion of the instrument.

The results in these cases are considered satisfactory, particularly when it is realized that this is a consecutive series of patients in which the balloon has been used.

Three examples of contralateral spread have occurred in the early cases of this series; fortunately they were all quite minimal and it was felt that they resulted from errors in technique which have since been corrected. One spread occurred in a pneumonectomy for tuberculosis with secondary bronchiectasis. The operation took place at 8:30 in the morning, the patient had not had adequate postural drainage, and bronchoscopy was difficult because of poor anesthesia. During operation bronchial occlusion was perfect, atelectasis was complete, and suction of the tracheobronchial tree was not necessary at any time. Despite this there was a definite small contralateral spread which slowly cleared on the patient's return to the sanatorium (Fig. 4). In the second case, a pneumonectomy for carcinoma, a sharply curved endotracheal tube prevented

PRIMARY RIB TUMORS

SURVEY OF LITERATURE AND A REPORT OF SEVEN ADDITIONAL CASES

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HEDBLOM[1] in 1933 reported 291 cases of tumors of the bony chest wall, collected from the literature and from his own records. However, this number is not a true indication of the incidence of primary rib neoplasms since this group included inflammatory lesions, secondary growths, and neoplasia unclassified because of incomplete data.

In 1942 Sommer and Major[2] analyzed 81 proved cases of primary rib tumors reported subsequent to Hedblom's review, including 15 cases of their own. This number provides a more accurate indication of the incidence of these lesions.

The purpose of this paper is to list those cases described in the literature since the report of Sommer and Major, to review briefly clinical facts regarding rib tumors, and to report 7 cases of primary rib tumors treated at the State University of Iowa Hospitals. Table I shows these collected cases.

Primary tumors of the ribs present no clinical characteristics not found in similar tumors occurring elsewhere in the bony skeleton. Because of their location they do present certain diagnostic problems and surgical considerations which may well be reiterated.

The most important symptoms of rib neoplasms are pain and tumor. Pain persisting over a long period of time is probably a more reliable and constant finding than the presence of tumor since the growth may protrude little if any above the normal contour of the chest wall. Also, pain may develop before a mass is recognizable either clinically or roentgenographically. The pain is usually dull and boring in character and is not affected by respiration early in the progress of the disease, but later it may become pleuritic in character. Severe pain is most frequently associated with malignant growths. Fever, weight loss, dyspnea, palpitation, mild gastrointestinal distress, and pleurisy are other symptoms which occur rarely. In our series of 7 cases, pain was the initial symptom in 3 and was noted later in 2 additional cases; a tumor was the primary symptom in 3 and was noted later in two additional cases. One patient (Case 7) had pain but no tumefaction. Another, who was found to have a fibrous dysplasia of rib, had neither pain nor a mass.

The significance of trauma in the causation of neoplastic growths has been mentioned in practically every article concerning rib tumors.[1, 5-10] Just how

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Read (by title) at the Twenty-Seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

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the withdrawal of the balloon for several seconds, and finally had to be removed with the balloon. The bronchus was not clamped until the tube had been removed and consequently spillage of bronchial secretions may have occurred at this time (Fig. 5). The last example concerned a pneumonectomy for tuberculosis in which a small shadow appeared in the apex of the opposite lung on the third day, and showed definite clearing within one week's time (Fig. 6). During the operation the balloon functioned perfectly, and there was no break in technique to explain the spread.

This discussion is intended primarily as a report of the clinical application and the development of a technique for the use of an instrument which successfully occludes a bronchus during pulmonary resection. Any statistics on the reduced incident of spreads should be compiled from a large series of cases in which the use of this instrument is combined with the improved methods of pre- and postoperative care which have been discussed.

SUMMARY

Various methods for the prevention of transbronchial spreads during pulmonary resection for suppurative diseases have been used during the past few years. In an attempt to eliminate the faults apparent in these methods, an endobronchial balloon has been developed which has been successfully used in 23 cases. For the use of this instrument a technique has been developed which includes preoperative and postoperative care as well as the actual insertion and placement of the instrument.* It is hoped that the incidence of postoperative spreads may be greatly reduced by this method.

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*This instrument is to be available through the George P. Pilling & Son Co., Philadelphia, Pa.

TABLE I

AUTHOR	CASE NO.	SEX	AGE	RIB SITE	INITIAL SYMPTOM	OTHER SYMPTOMS	DURATION	TREATMENT	RESULTS
					Chondrosarcoma				
Harper	1	F	60	7, 8 anteriorly	Pain	Dyspnea, tumor	10 yr.	Surgery	No recurrence at 9 mo.
Mayer	2	F	47	3 anteriorly	Tumor	Pain	3 yr.	Surgery	No recurrence at 5 yr. 3 mo.
Janes	3	M	60	9, 10, 11 anteriorly	Tumor	None	2 yr.	Surgery	No recurrence at 18 mo.
Janes	4	M	39	4 posteriorly	Pain & tumor	None	2 yr.	X-ray & surgery	No report
Janes	5	M	16	9 posteriorly	Dry cough	Pleural pain, shortness of breath	?	None	Died 1 mo. after onset
Janes	6	M	45	9, 10 anteriorly	Tumor	None	15 yr.	Surgery, local exc.	No recurrence at 2 mo.
Dorner & Marcy	7	F	51	11 laterally	Pain	Tumor	4 yr.	Surgery	Died 1 yr. later, metastasis?
Dorner & Marcy	8	M	56	6, 7 laterally	Tumor	Pain	3 yr.	Surgery, palliative	Died 3 mo. after op.
					Osteochondroma				
Janes	9	F	24	anteriorly	Tumor	None	8 yr.	Surgery	No recurrence at 12 yr.
Janes	10	M	51	1 anteriorly	Tumor	Pain	6 mo.	Surgery	Not stated
Bertola & Martinez	11	F	38	4 anteriorly	Tumor	None	1 yr.	Surgery	Not stated
Dorner & Marcy	12	F	33	2 anteriorly	Tumor	None	15 yr.	Surgery	No recurrence at 16 mo.
					Chondroma				
Janes	13	F	64	1, 2 anteriorly	Tumor	None	approx. 50 yr	Surgery	No recurrence
Janes	14	F	65	anteriorly	Tumor	None	30 yr.	None	Died of intercurrent infection

important a role it plays is not yet clear. A history of local trauma was so frequently found in the reported cases that the traumatic factor may possibly be significant. Speed[20] stated that the majority of malignant tumors of the chest which appeared following trauma occurred in males and that the most common site was the anterolateral chest wall, the area most exposed to blows and falls. Hedblom found that 13 of 61 cases of sarcoma occurred in previously traumatized areas.[1] One case was reported wherein trauma occurred eighteen years prior to the appearance of a chondrosarcoma in rib.[6] The history of injury and subsequent distress during those many years was so clear cut that its contribution to the production of the tumor seemed difficult to deny. In a clinicopathologic conference at the Massachusetts General Hospital a case was presented in which an injury antedated a cavernous hemangioma of the rib by fifteen years. The history of a close relationship between the original trauma and the appearance of the tumor was such that coincidental occurrence seemed unlikely. One patient in our series (Case 2) developed a chest wall mass ten days after an injury to this area. The mass gradually enlarged and at operation six months later a fibrosarcoma was found.

Although the reports regarding trauma seem quite convincing, we are not ready to accept the theory of trauma as a causative factor in the development of bone tumors. More likely, a traumatic incident serves only to focus attention on a previously existing, asymptomatic pathologic lesion, whose presence was unknown before the injury occurred. We would therefore emphasize the fact that a previous injury does not permit a conclusion that persisting symptoms are resultant or insignificant. We feel that patients with pain and/or swelling which continues after trauma should be studied thoroughly for the presence of a tumor. Blake and Bradford have pointed out that too many cases are reported wherein roentgenograms have not been utilized, nor has there been an adequate physical examination in patients who complain of (a) persistent pain at the site of an injury over a period of time considerably longer than is required for healing of the injury to take place; (b) the appearance of a mass at the site of an old injury; (c) recurrence of pain at the site of an old injury after a lapse of months or years, when no immediate cause is apparent.[3] The fact that pathologic fractures may occur with minor trauma should be kept in mind. No complaints, such as those just mentioned, should be dismissed without complete x-ray studies even though the physical examination proved to be negative.

After one has made a diagnosis of disease in the thoracic cage, there are certain conditions which may be difficult for him to differentiate from rib tumors: These include tuberculous and pyogenic osteomyelitis of the spine or ribs. Syphilitic lesions must be considered as possibilities on occasion, although less frequently now than previously. Careful histories and routine blood and spinal fluid studies are important and will usually clarify the problem. Intrathoracic nerve tumors or tumors of the posterior mediastinum may occasionally be mistaken for bony chest wall lesions. Likewise, intercostal nerve tumors may simulate rib tumors clinically and roentgenographically. Case histories have also been presented wherein rib tumors have been erroneously diagnosed and treated as simple contusions and fractures.[7, 9, 13] Lesions of the pleura, lung, and soft tissues of the chest wall (including aneurysm, cold abscess, encapsulated empyema, empyema necessitatis, and bronchiogenic carcinoma) have in some instances resembled bony tumors.

One of the most difficult problems, after demonstrating a bone neoplasm roentgenographically, may be the clinical differentiation between a primary and secondary growth. The ribs are involved by metastasis much more frequently than by primary growth. Ordinary methods of clinical examination may fail to disclose the source from which metastasis has occurred. Since secondary lesions in the ribs may become evident long before any symptoms are produced by the primary lesion, recognition of these facts is imperative.

A complete history and physical examination supplemented by the use of x-ray studies are the chief aids in diagnosing a rib tumor. In several of our cases, x-rays of most of the skeleton were taken to rule out polyostotic lesions. Likewise, special studies, particularly blood calcium, phosphorus, and phosphatase levels, were utilized to rule out diseases with secondary bone changes. Artificial pneumothorax and thoracoscopy after instilling air into the pleural cavity are diagnostic aids of probable importance in some instances. Some authors have suggested the use of aspiration biopsy, particularly to differentiate between primary and secondary tumors. This measure was not employed in our series. Exploratory biopsy remains a justified and essential procedure in those cases defying diagnosis by any other means and in which a positive diagnosis is necessary before management is instituted. Emphasis is made that this method is positively indicated in questionable cases rather than the frequently adopted plan of watchful waiting. It is apparent from the reports in the literature and from a review of our own cases that in too many instances there is a great delay between the onset of symptoms and the removal of the lesion. This is due in some cases to an unjustified wrong diagnosis and in others to a failure to identify lesions in their premalignant stage. For example, chondromas and osteochondromas are now recognized as being either potentially malignant from their onset or as having a tendency to become malignant later, and they demand adequate treatment at the time they are first noted.

The definitive treatment of primary rib tumors is no longer a controversial matter. There is little evidence that irradiation therapy is of real value. Except for two giant-cell tumors which responded favorably and a similar lesion apparently cured by radium therapy, there are no reports since 1933 of successful treatment by this means. Early and wide excision is the treatment indicated. By wide excision is meant removal of the rib including the periosteum and the underlying pleura well beyond the lesion along with the adjacent muscles (intercostals, chest wall, diaphragm, etc.). Not infrequently, reports state that the pleura has been stripped from a rib tumor rather than being widely excised. This was true in several of the earlier State University of Iowa Hospital cases, and in one instance (Case 1) we believe this fact was likely responsible for a recurrence. Entire removal, particularly of the first rib, for

					Fibrosarcoma				
Blake & Bradford	15	M	20	6 anteriorly	Pain	Tumor; loss of weight; anorexia	2 yr.	None, inoperable	Died 21 mo. after onset
Dorner & Marcy	16	M	37	9, 10 anteriorly	Pain	Tumor	6 mo.	Surgery	Died 9 mo. after op.
					Hemangioma				
Mallory	17	M	34	6 posteriorly	Pain	Loss of sensation to heat & cold, left arm	15 yr.	Surgery	No report
Dorner & Marcy	18	F	22	9 posteriorly	Tumor	Pain	8 yr.	Surgery	No recurrence at 8 mo.
					Osteochondrosarcoma				
Ferrari & Lentino	19	M	—	9 laterally	Tumor	None	20 yr.	X-ray & surgery	No recurrence at 2 yr.
					Plasmocytoma				
Gonzales & Boggino	20	M	60	4, 5, 6, 7 laterally	Pain	Loss of weight headache, chills	3 mo.	X-ray palliative	Died 5 mo. after onset
					Osteosarcoma				
Luque	21	M	—	7 posteriorly	Tumor	None	2 yr.	Surgery	No recurrence at 2 mo.
					Lymphocytoma				
Estovez	22	F	27	9 anteriorly	Pain	Tumor, loss of weight	2 yr.	Surgery	No recurrence at 3 yr.
					Osteoid Osteoma				
Ponseti & Barta*	23	M	11	9 posteriorly	Pain	None	8 mo.	Surgery	No recurrence at 2½ yr.
					Fibrous Dysplasia of Rib†				
Lichtenstein & Jaffe	24	(No clinical data given)							
Schlumberger	Cases 25-54 (29 cases reported)								
Dorner & Marcy	55	F	21	6 posteriorly	None. Found on routine x-ray	None	Unknown	Surgery	No recurrence at 10 mo.

*Case 7 in our group, reported in J. Bone & Joint Surg. 29: 767-780, 1947.

†These cases of fibrous dysplasia are listed with primary tumors of ribs chiefly because of their significance in differential diagnosis. In the 29 cases reported by Schlumberger, there was a wide range of diagnoses both by the roentgenologists and by the pathologists first studying the specimens. Almost all of these lesions were originally mistakenly diagnosed. Recognition of the true nature of these lesions is very important from a prognostic standpoint since the outlook is much better in these cases than in most bone tumors with which they are mistaken.

Pathology.—Microscopic Description (Fig. 1, *B*): This tumor was similar in appearance to the previous specimens. As in the recurrent mass removed from the rib, this tumor was composed predominantly of fairly immature hyaline cartilage. However, there was fairly conspicuous calcification in some portions of the matrix. In sections of the same tumor removed at preliminary biopsy, one could see invasion into the buccal submucosa. The invading portion of the tumor was distinctly primitive in appearance.

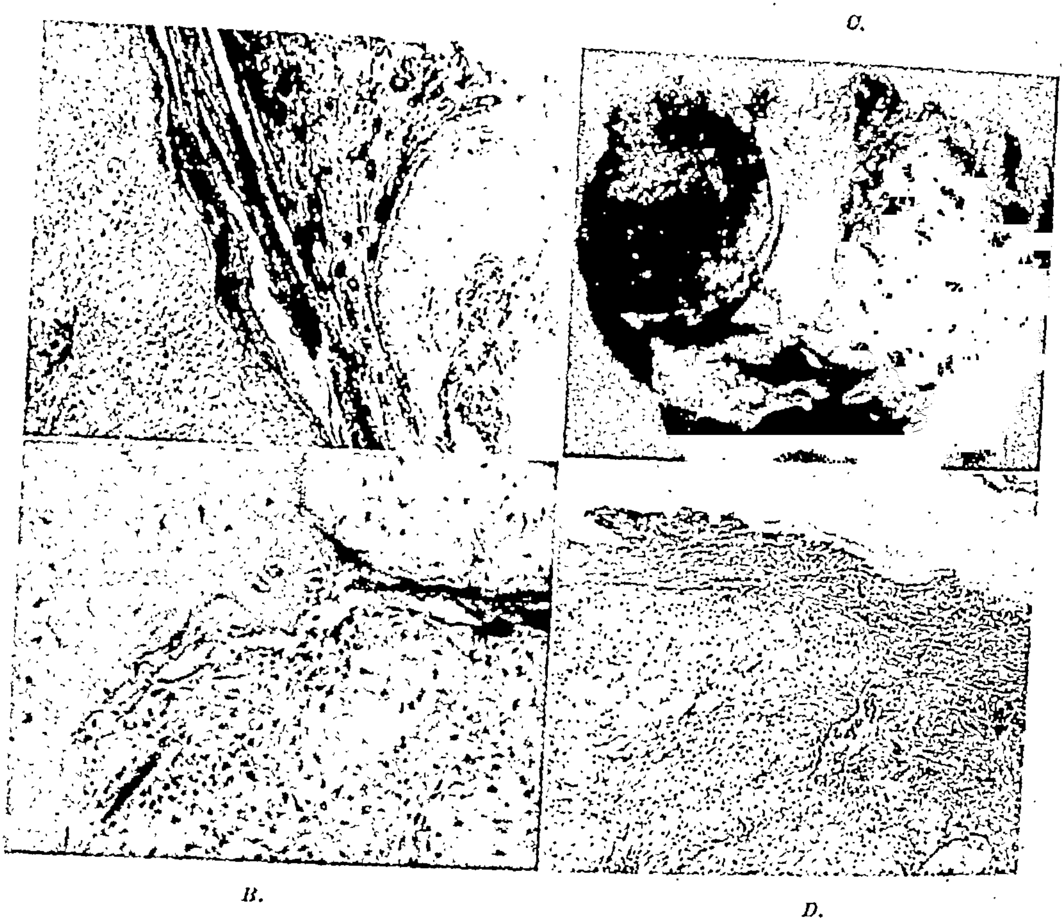


Fig. 1 (Case 1).—*A*, Photomicrograph (low power) of chondrosarcoma of rib showing pleomorphic character with watery cartilage matrix to the right of the connective tissue septum and fairly dense matrix with more mature cartilage cells to the left of the septum.

B, Photomicrograph (high power) of chondrosarcoma of mandible showing two lobules of primitive cartilage adjacent to more mature partially calcified hyaline cartilage. Note resemblance to tumor of rib above.

C, Photograph of recurrent chondrosarcoma of rib. The dense white band in the center is the pseudocapsule which has been laid open revealing the everted friable hyaline cartilage.

D, Photomicrograph of recurrent chondrosarcoma of rib shown above, showing immature neoplastic cartilage invading the tumor's pseudocapsule.

Discussion.—We feel that the first operation was inadequate. The overlying muscles, pleura, and intercostal muscles should have been widely excised. In resecting any tumor of rib it should never be stripped from its underlying pleura. The recurrence in this case may well have been due to this mistake in technique.

Regarding the lesion of the mandible—one may speculate as to the relationship of this tumor and those of the rib. We feel that this probably was not a metastasis but rather a new tumor. The patient may have had enchondral rests and for some reason these developed as chondrosarcomas. On the other a malignancy involving any portion of it, is advocated by Fort,[5] since partial resection in this extremely vascular area is frequently followed by early infiltration and rapid general metastasis. (In our Case 6 we removed not only all of the ninth rib and the underlying pleura and the eighth and ninth intercostal muscle bundles, but also a segment of the eighth rib in the region of the mass so as to facilitate wider excision. The microphotograph of this case [Fig. 6, *D*] shows the close relationship of the tumor capsule and the pleura. Obviously, if stripping of this tumor from the pleura had been attempted, complete removal would not have been accomplished)

In the following cases of primary rib tumors the patients have been operated upon at the State University of Iowa Hospital from 1934 to September, 1946.

CASE REPORTS

CASE 1.—F. T. G., a white woman, first entered the State University of Iowa Hospitals in 1934 at the age of 51 years, with a complaint of a mass on the lower left part of the chest of twenty years' duration. On physical examination there was a hard, slightly nodular, nontender mass measuring 15 by 10 by 10 cm. in the left posterior axillary line lying between the tenth and twelfth ribs. The mass was excised along with a fairly generous segment of the eleventh rib, from which it arose. The operator's note included the statements: "The mass peeled out quite readily, the only technical difficulty encountered being separating the thinned out pleura which had been displaced by the inward growth of the tumor."

Pathology.—Gross Description: The mass measured 15 by 11 by 10 cm. To it was attached a rib 3.5 cm. in length. The tumor appeared to rise from the end of the rib. The cut section revealed chiefly cartilage, but a few areas of bone were seen.

Microscopic Description (Fig. 1, *A*): Microscopic slides showed neoplastic cartilage, pleomorphic in appearance. In some areas the cartilage was lobulated and the cartilage matrix was dense. Here the cartilage cells tended to be large, ovoid, and irregularly distributed in the matrix. The matrix in some areas showed irregular focal calcification. In other areas the tumor was composed of much more embryonal cartilage; here the matrix was watery in appearance and devoid of calcification. Cartilaginous lacunar outlines were difficult to ascertain and the individual cartilage cells were more pleomorphic. Many of them were spindle-shaped and had long tapering cytoplasm. No mitotic figures were seen.

The diagnosis in 1934 was "chondroma of rib." However, because of the evidence of a mixture of mature and embryonal cartilage, we would now call this tumor a low-grade chondrosarcoma.

This tumor *did* recur. On the patient's second admission to the hospital in 1945, a recurrence which she had noted for the past two years was excised. This arose subjacent to the old operative scar.

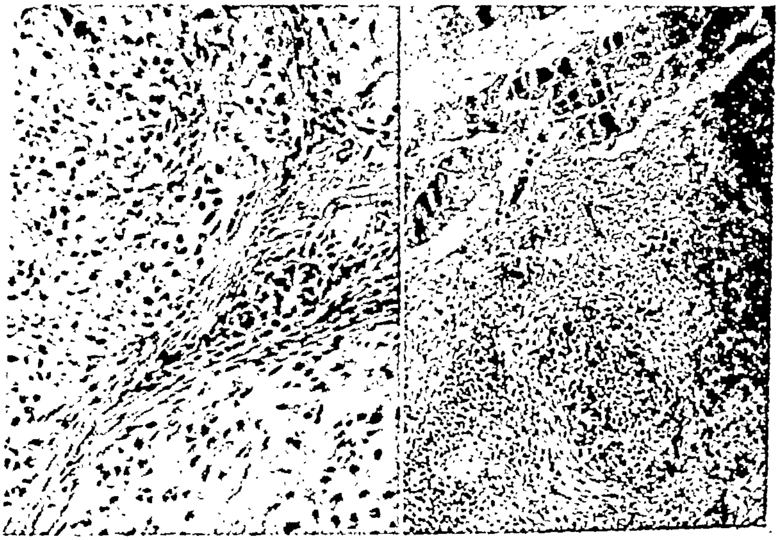
Pathology.—Gross Description (Fig. 1, *C*): A 7 by 7 by 6 cm. well-circumscribed mass of cartilaginous tissue surrounded by a rather thick pseudocapsule was found. Upon sectioning, the tumor tissue bulged beyond its pseudocapsule.

Microscopic Description (Fig. 1, *D*): There were several sections of pleomorphic neoplastic cartilage similar in appearance to the original tumor. In these sections, however, a more immature type of cells and matrix predominated. Invasion of the pseudocapsule was seen in one area. There was minimal matricial calcification. No endochondral ossification was seen.

The patient's third admission was in September, 1946, in the department of otolaryngology, because of a mass in the left side of the mandible which had been noted two months previously. A diagnosis of chondrosarcoma was made and, following biopsy, the left external carotid artery was ligated and the mandible was excised. The patient suffered secondary shock and died about eight hours postoperatively. No autopsy was performed. The pathologic diagnosis was chondrosarcoma of the mandible.

of sixth and seventh ribs.'' Recurrence was noted six months later, however eighteen months elapsed before the patient was referred to the State University of Iowa Hospital. On Jan. 29, 1938, after preoperative pneumothorax, exploratory thoracotomy was performed. The lesion was found to be inoperable because of metastasis to the pleura and to mediastinal lymph nodes; therefore, a palliative excision was carried out. The pathologic diagnosis was osteochondrosarcoma, recurrent. He was discharged on the thirty-fourth postoperative day and died two months later.

Pathology.—Gross Description: The specimen consisted of an irregular, lobulated, nodular mass measuring 20 by 6 cm. This mass was soft in some areas and bony hard in others. Portions of rib could be seen here and there protruding from the mass. One area was cystic and contained yellowish, thick, viseid material. The mass was partially encapsulated. On cut section it was composed of irregular nodular masses of grayish-white tissue intermingling with fibrous tissue. There were areas of necrosis, hemorrhage, and calcification.



A. B.

Fig. 3 (Case 3).—*A*, Photomicrograph (high power) of recurrent chondrosarcoma of rib showing immature cartilage with connective tissue septa. *B*, Photomicrograph (low power) of recurrent fibrosarcoma of rib showing invasion of muscles of the chest wall.

Microscopic Description (Fig. 3, *A*): Sections showed lobulated masses of neoplastic hyaline cartilage tumor, surrounded by a dense fibrous tissue stroma separating this into lobules. These fibrous tissue septa were in many places dense, broad, and occasionally calcified. The cartilage neoplasm varied considerably in cellularity but predominantly was more cellular than normal hyaline cartilage. In the cellular areas the matrix was predominantly light-staining and devoid of calcification. These areas frequently appeared frankly myxomatous. In other areas the matrix was sparsely cellular and showed varying degrees of calcification. This calcification was the site of ossification in many areas. The ossification was predominantly by direct osteoblastic apposition. The osteoblasts and the bones thus formed did not appear neoplastic but were a reactive response to the calcified material. There were small areas where the neoplastic cartilage cells were distinctly pleomorphic and varied considerably in size, shape, and depth of staining. In one section lobules of neoplastic cartilage were seen pushing into skeletal muscle. A thin barrier of flattened connective tissue separated the two (Fig. 3, *B*).

Diagnosis was chondrosarcoma of rib.

CASE 4.—D. C., a 33-year-old-white woman, entered the State University of Iowa Hospitals on Feb. 11, 1946, complaining of a painless mass in the region of the left second costochondral junction of fifteen years' duration. It had been increasing in size for some hand, the similarity of the microscopic pictures might lead one to believe that the lesion in the mandible was a metastasis which might have been avoided had an early wide excision of the primary tumor of rib been carried out.

Case 2.—J. H. a 37-year-old white man, was admitted to the State University of Iowa Hospitals on May 12, 1938. He complained of a mass on the left side which had appeared ten days after a fall on the chest in November, 1937. Surgical removal had recently been attempted at another hospital but had failed. Examination revealed a mass, 12 by 8 by 6 cm. in size, which occupied the region of the costal margin on the left and was adherent to the ninth and tenth ribs (Fig. 2, *A*). A block resection of the mass was carried out, removing the eighth, ninth, tenth, and eleventh ribs together with their costal cartilages and the underlying endothoracic fascia and pleura.

Pathology.—Gross Description: The mass measured 12 by 5 by 4 cm. One rib disappeared into a hard mass measuring 7 by 5 by 5 cm. This mass was quite well encapsulated and on cut surface was composed of translucent grayish tissue.

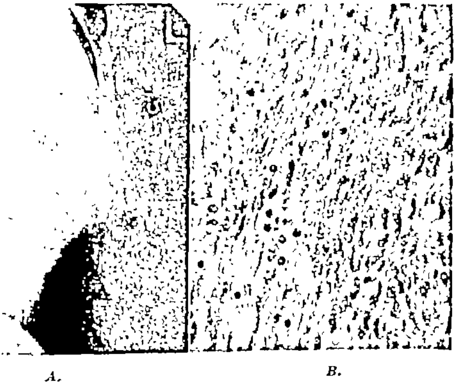


Fig. 2 (Case 2).—*A*, X-ray view of fibrosarcoma of rib showing destruction of rib and the soft tissue mass. *B*, Photomicrograph of fibrosarcoma of rib showing spindle cells and numerous mitotic figures.

Microscopic Description (Fig. 2, *B*): Sections showed interlacing bundles of neoplastic cells which were spindle-shaped and had elongated oval nuclei. These cells tended to run in parallel direction, forming loosely packed whorls and long sheets and interlacing bands. Variation in cell size and depth of staining was frequent. Mitotic figures were abundant. Invasion of bone and adjacent soft tissue was widespread. There was considerable periosteal elevation with formation of immature subperiosteal new bone. In areas scattered throughout the periphery of the tumor there was nonneoplastic new bone formation. Some of this was represented by immature osteoid tissue.

The diagnosis of fibrosarcoma of rib was made.

The patient resumed work as a sawmill engineer two and one-half months after operation and worked for a period of about five months. He died nine months after operation with widespread metastases as suggested by a letter received shortly after his death.

Case 3.—C. W., a 56-year-old white man, was admitted to the State University of Iowa Hospitals on Jan. 21, 1938, complaining of a growth in the right chest wall for the past three years. The mass together with the sixth and seventh ribs had been resected two years previously at another clinic. The diagnosis had been "grade I fibromyxochondrosarcoma

Discussion.—Although this was diagnosed as a benign lesion, we feel that when osteochondromas of ribs arise they should be removed early by block resection rather than "watching them for any change" as had been done in this case for fifteen years.

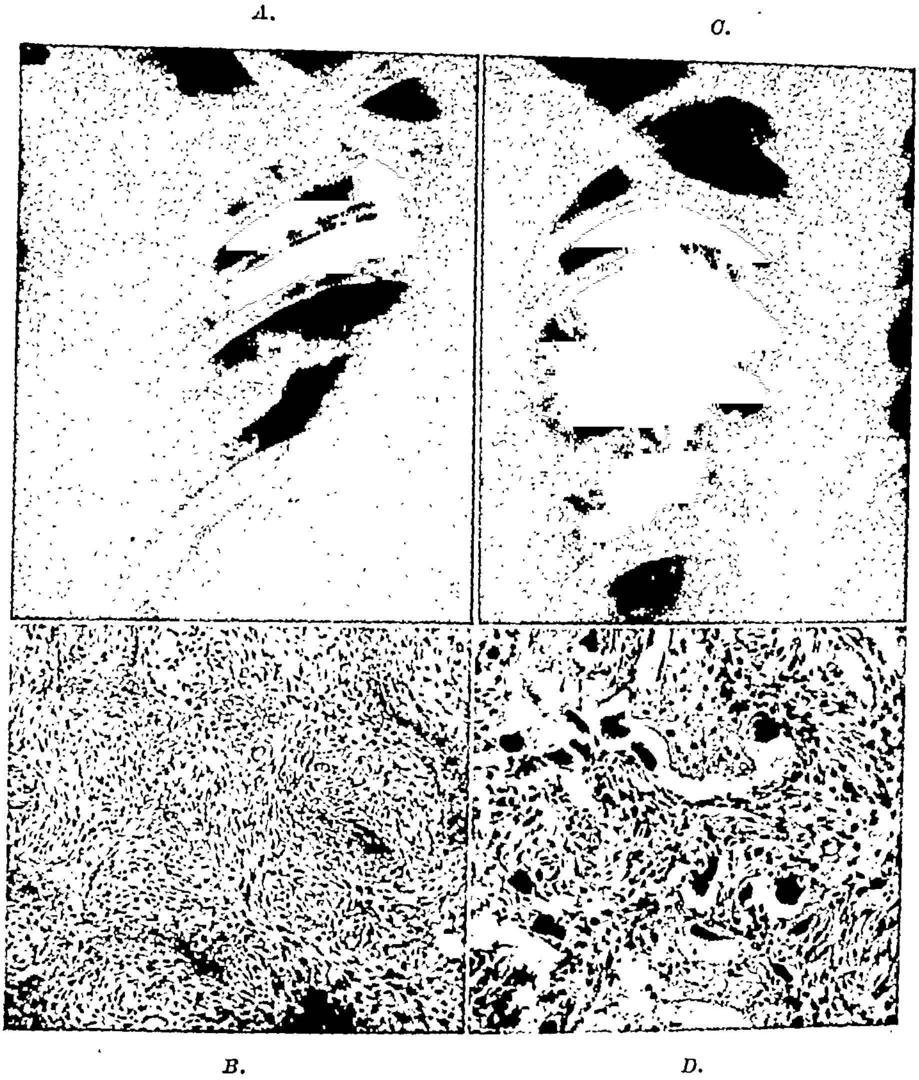


Fig. 5 (Case 5).—*A*, Preoperative x-ray of patient with fibrous dysplasia of left sixth rib. *B*, Photomicrograph (low power) of fibrous dysplasia of rib showing a fairly typical area of young fibrous tissue in marrow cavity containing delicate osteoid trabeculae. *C*, Postoperative x-ray. *D*, Photomicrograph (high power) of fibrous dysplasia showing multinucleated giant cells in cellular fibrous tissue and in Howship's lacunae.

CASE 5.—P. M. O., a 21-year-old white woman, a nurse, incident to a routine chest roentgenogram, was found to have a tumor of the left sixth rib (Fig. 5, *A*). She had no complaints. Laboratory studies revealed the blood and urine to be negative. The Wassermann was negative. Blood calcium, phosphorus, and phosphatase studies were within normal limits. X-ray films of the pelvis, both femurs and knees, both shoulders, mandible, and spine showed no evidence of bony disease. On July 7, 1946, a block resection of the involved rib was carried out, extending more than 2 cm. beyond the palpable tumor on each side and including the adjoining intercostal muscles and the underlying pleura. The patient's postoperative course was uneventful. Recent follow-up examination and x-ray films show no evidence of recurrence.

time (Fig. 4, *A* and *C*). On Feb. 13, 1946, the mass was excised, including cartilage and rib, well away from the gross tumor. Included in the block resection were the adjacent intercostal muscles and underlying pleura. The defect of the chest wall was closed with the pectoralis minor muscle.

Pathology.—Gross Description (Fig. 4, *B*): The specimen consisted of a section of rib 7.5 by 4 by 4 cm., to which was attached intercostal muscles. The central portion was greatly widened and was composed of lobulated masses of cartilage. One surface was covered by shiny pleura. On section the lobulated masses were seen to be composed of dense cartilage. The overlying pleura was thin but intact. The attached tissues appeared to be displaced rather than invaded.

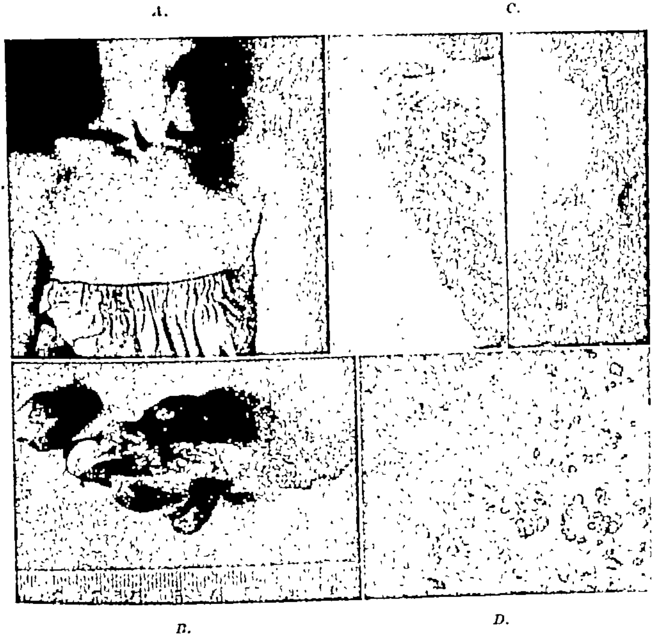


Fig. 4 (Case 4).—*A*, Photograph of patient showing tumor caused by osteochondroma arising at the left second costochondral junction. *B*, Osteochondroma of second rib with attached intercostal muscle and pleura. *C*, Posteroanterior and oblique x-ray views of osteochondroma of left second costochondral junction. *D*, Photomicrograph of osteochondroma of rib showing areas of calcification in relatively mature hyaline cartilage.

Microscopic Description (Fig. 4, *D*): Sections taken from various areas in the periphery revealed varying degrees of cartilage maturity. In some areas there was fairly mature hyaline cartilage with disorderly calcification and cartilage cell column arrangement. There were numerous scattered focal areas of senescence and calcification. Sluggish endochondral ossification was seen. A few areas in the perichondrium showed more immature cartilage with multifocal areas of proliferation. However, this did not appear to be invasive in nature and the appearance was consistent with that of a benign cartilaginous tumor.

Diagnosis was osteochondroma of the second rib on the left.

The patient's postoperative course was uneventful. A recent follow-up report from the physician for whom the patient works states that she is well at the present time.

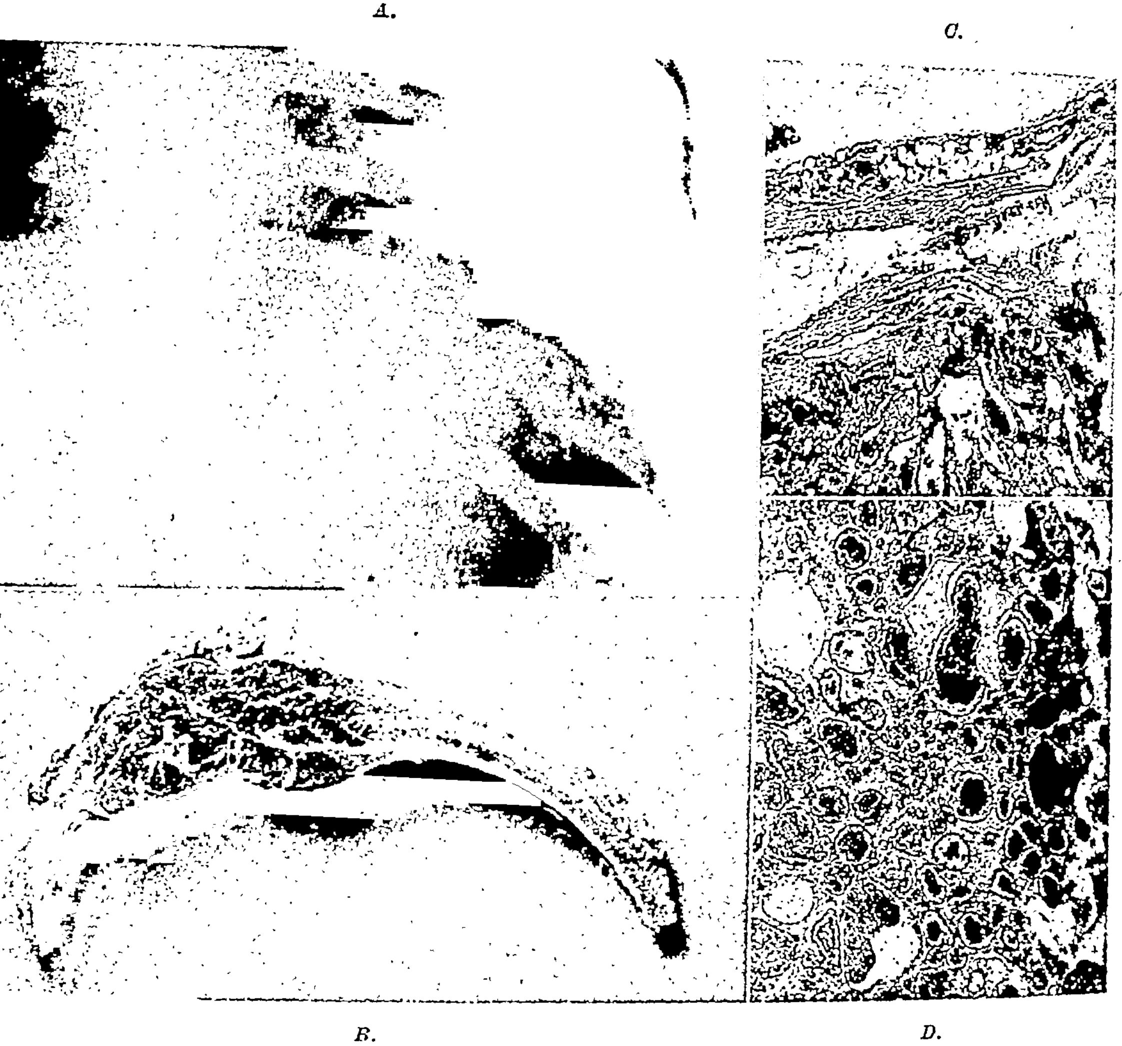


Fig. 6 (Case 6).—*A*, X-ray of hemangioma of left ninth rib. *B*, Photograph of rib involved by hemangioma after partial fixation in formalin and longitudinal sectioning. *C* and *D*, Composite photomicrograph of hemangioma of rib. Note the very thin capsule separating the tumor from the pleura.

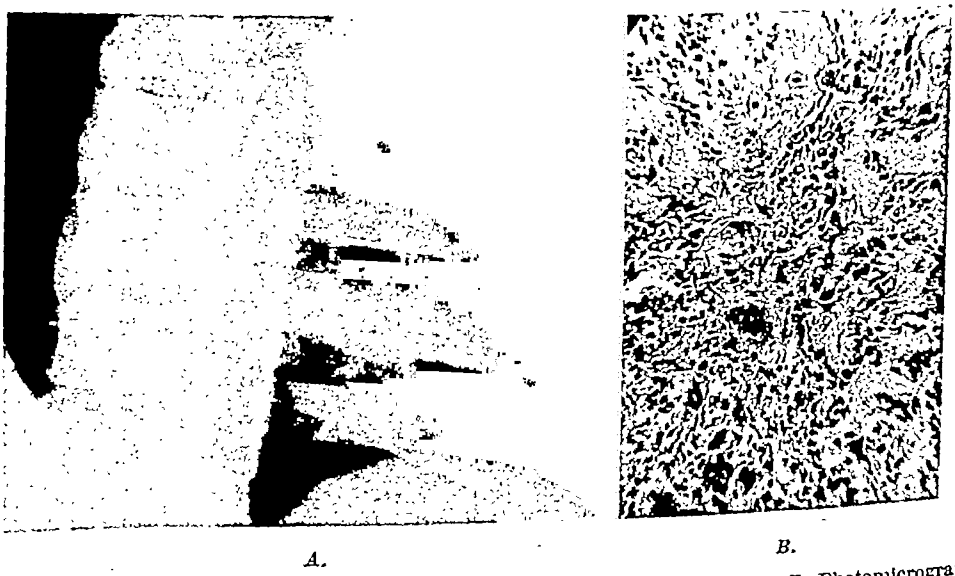


Fig. 7 (Case 7).—*A*, X-ray, view showing osteoid osteoma of left ninth rib. *B*, Photomicrograph of osteoid osteoma of rib.

Pathology.—Gross Description: The specimen was a 7.5 cm. segment of rib. In the 4.5 cm. of one extremity the medullary canal was dilated from the normal width of 2 mm. to 6 mm. At one extremity of this widened portion was a softened, round, translucent area. The trabeculae of bone were condensed around this mass.

Microscopic Description (Fig. 5, *B* and *D*): The marrow space of the rib was replaced by masses of young fibrous tissue appearing in whorls and interlacing bands. In some areas there was direct metaplasia to bone in this cellular fibrous tissue. This bone was seen in the form of slender delicate irregular trabeculae. Many of these were represented by immature osteoid tissue which blended into the young fibrous tissue. The conspicuous osteoblastic appositional bone formation seen in osteoid osteoma was lacking. In some areas there were fairly numerous multinucleated giant cells lying in apposition to reactive new bone and in the cellular fibrous tissue. Some of these were lying in large Howship's lacunae. No blood pigment or lipoid-laden cells were seen.

Diagnosis was fibrous dysplasia of rib.

Discussion.—This case is quite typical of fibrous dysplasia of a single bone. As in 12 of 29 cases reported by Schlumberger, this case presented no complaints; it was found on routine x-ray of the chest. The histologic picture is similar to the changes in the "Albright syndrome." However, this patient presented no abnormal pigmentation of the skin nor any endocrine dysfunction. Lichtenstein and Jaffe, Schlumberger and others have described this lesion in considerable detail. The prognosis is good.

CASE 6.—C. S., a 22-year-old white woman, was admitted to the State University of Iowa Hospitals on Sept. 5, 1946. In 1938 she had noted a swelling which she described as being about "one-half the size of a hen's egg" in the region of the left ninth rib posteriorly. This was sore to pressure. There was never any local redness nor systemic reaction. The lump lasted about one week and then it and the associated symptoms disappeared. Approximately three weeks before admission to the State University of Iowa Hospital the patient again developed a sharp pain and soreness in this region. The local doctor took x-rays and noted a tumor of the left ninth rib (Fig. 6, *A*). He then referred her to the State University of Iowa Hospital.

Physical examination revealed a firm mass on the left ninth rib posteriorly, about 3 by 3 by 3 cm. in size, extending from the posterior axillary line posteriorly about 4 cm. It was not tender and there was no local erythema. Laboratory studies revealed the urine to be negative. Blood counts, and blood calcium, phosphorus, and phosphatase determinations were within normal limits.

On Sept. 6, 1946, a block resection of the entire left ninth rib including adjacent intercostal muscles and underlying pleura was carried out. A segment of the eighth rib was also removed to facilitate wider excision. The postoperative course was complicated by hemothorax which responded satisfactorily to thoracenteses. Recent follow-up reports from the patient's referring physician state that she is in perfect health. Roentgenograms show no evidence of recurrence.

Pathology.—Gross Description (Fig. 6, *B*): The specimen consisted of a segment of rib measuring 16 cm. in length. Near the vertebral end of the rib the normal structure was replaced by an intrinsic tumor which measured 4.5 cm. in its greatest diameter. In the other diameter it was 4 cm. Its length along the course of the rib was 8 cm. The tumor was fusiform in shape. On external inspection there was no gross evidence of the tumor breaking through the parietal pleura or the intercostal fascia. However, in one spot there was a short tear in the parietal pleura which may have extended into the tumor. After sectioning the rib in longitudinal direction after partial fixation in formalin, it was seen that there was only a shadowy outline of the pre-existent osseous structure of the rib. This outline showed some expansion and irregular replacement with soft friable red tumor. Peripheral to the outline of the rib structure, there were radiating spicules of rather friable new bone

SUMMARY

1. The literature regarding primary rib tumors has been briefly reviewed. Fifteen cases since a comprehensive review by Sommer and Major in 1942 are listed. Seven additional patients operated on at the State University of Iowa Hospital are reported upon.

2. Pain and tumor are the most frequent complaints.

3. Trauma as a possible etiologic factor is discussed. We believe that pain and/or a tumor persisting after trauma should not be considered lightly but should be investigated thoroughly as possibly being due to a rib tumor.

4. The diagnosis of primary rib tumor is discussed in some detail.

5. We believe that early wide excision including resection of periosteum, underlying pleura, and adjacent muscles is the treatment of choice for all primary rib tumors.

Addendum.—Since this paper was submitted for publication another patient with a primary rib tumor has been treated. The patient, a 33-year-old white man, had had a painful tumor of the left tenth rib for at least one year. The mass had been biopsied in December, 1947, and was found to be an osteochondromyxosarcoma. X-ray treatment was given. On March 29, 1948, at the Iowa Methodist Hospital, a radical excision, including a portion of the diaphragm which was invaded by the tumor, was carried out. When last checked on July 30, 1948, the patient appeared well.

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in the so-called "sunray" appearance. *In some areas there was more of a "honeycombed"* appearance and the interstices were filled with this same rather mushy red tumor tissue which grossly resembled hemangioma. At the vertebral borders of the tumor extending in nodular manner under the parietal pleura the tumor appeared to be composed more largely of soft tissue with less reactive new bone. One margin of the tumor was composed of rather homogeneous firm yellow material. At this place it was tightly attached to overlying intercostal fascia.

Microscopic Description (Fig. 6, *D*): *In all the sections decalcified there was evidence* of hemangiomatous tissue which was invading and replacing the normal bone and marrow. Large blood-filled venous cavernae lined by venous endothelium varied greatly in size. These were present between active and sclerosing trabeculae of bone. The supporting structure of the vascular elements was composed of cellular connective tissue and a reticulum containing some interstitial fluid and hyalinized tissue. These supporting cells contained no mitoses. The supporting tissue contained some lymphocytes and some extravasated red blood cells. Bony *trabeculae showed some destruction and irregular formation with irregular* lamellae and cellular arrangement. The periosteum was for the most part intact about the cortical limits, but one area suggested outgrowth through periosteum. No extensive signs of invasion or malignant tendencies were present in any sections. In no place did the tumor show invasion of pleura, but in some areas it was separated from the pleura by only a very thin capsule (Fig. 6, *C*).

Diagnosis was hemangioma of the rib.

CASE 7.*—W. W., Jr., a 11-year-old white boy, was admitted to the State University of Iowa Orthopedic Clinic on Sept. 7, 1944, with a complaint of pain in the region of the left ninth rib for the past seven to nine months (Fig. 7, *A*). On Nov. 21, 1944, a subperiosteal resection of the proximal 2¼ *inches of the left* ninth rib was carried out. The clinical diagnosis was enchondroma or osteoid osteoma. The last follow-up examination on April 11, 1945, showed no recurrence.

Pathology.—Gross Description: There were three pieces of bone representing the proximal portion of the ninth rib. There was a tumor 1 inch long and ⅝ inch thick, covered by apparently normal cortex. Inside there was a mass of sclerotic, whitish irregular bone. No cartilage could be seen macroscopically.

Microscopic Description (Fig. 7, *B*): Two slides were studied. The tumor mass was made of osteoblastic tissue with abundant bone formation. In the center of the mass this bone was quite dense but at the periphery the osteoid was very immature, irregular, and the osteoblasts were quite anaplastic in appearance. In the cellular peripheral areas many of the osteoblasts had abnormally large and hyperchromic nuclei. Scattered mitoses were present. This area resembled osteogenic sarcoma and in one area the cortex of the rib was being invaded.

Diagnosis was *osteoid osteoma*, unusually cellular—anaplastic at margins.

Discussion.—The clinical course together with central sclerosis gives the typical picture of an osteoid osteoma and it is felt that the lesion is probably classified in this group. Because of the extreme anaplasia and cellularity peripherally it is felt that the prognosis should be somewhat guarded.

Three patients (Cases 4, 5 and 6) were operated upon by one of the authors (R.A.D.) with the policy of wide excision being carried out. These three, as well as one other (Case 7), are still alive and well; the others have died. We would not imply that the wide excision in Cases 4, 5, and 6 is responsible for the patients' survivals but wish only to emphasize our present policy of this type of therapy for all primary tumors of rib.

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*This case was reported with a series of osteoid osteomas in J. Bone & Joint Surg. 29: 767-780, 1947.

Before operation this boy had developed certain complications, any of which might have proved fatal. First, the convulsions in the left side of the body, followed by a partial paralysis of the left foot, may have been caused by thrombosis, as is so often seen in patients with a polycythemia. It is also not improbable that the cerebral symptoms may have been due to the entrance of air into the vessels, at the moment of the rupture of a cavernous space in the lung, particularly in this case, since the convulsions and hemoptysis occurred simultaneously.

Second, during the last few years some dilatation of the heart both to the right and left had occurred. So it is probable that, without operation, a decompensation of the heart would have occurred after some time.

Third, the quantity of blood which was expelled during the hemoptysis was large and it is possible that with a subsequent hemoptysis he might have drowned in his own blood, as recorded in some of the published cases.

It is important to note that in all the published cases of angioma of the lung, other blood vessel tumors, if they were present, were always situated on the head and specially on the lips or at the back of the neck, as in this particular patient. A possible explanation of this may be that since embryologically the lungs are developed from a groove in the ventral wall of the pharynx, or in the head, it seems reasonable to assume that tumors arising from the mesenchyme in this region may be found in both the lung and the head. There were similar findings in the cases of Janes,[1] Mackler and Zion,[2] Lindgren,[3] and Goldman.[4] It is our opinion that these cases strengthen the theory of congenital origin of cavernous angiomas of the lung. The angiomas found in the family of the patient, who has been described by Adams, Thornton, and Eichelberger,[5] were also situated on the head. These latter cases even suggest the probability of the disease originating in the germ cell.

The same theory is sustained also by the cases described by Goldman,[4] which concern two brothers, who both suffered from angioma of the lungs.

So it must be possible to find this disease in very young children. Most of the cases published up to this time concern adults. And as the disease is progressive and after many years shows a dangerous influence on the heart, the angioma of the lung should be operated upon as early as possible.

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CAVERNOUS ANGIOMA OF THE RIGHT LUNG

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THE number of cases of cavernous angioma (fistula arteriovenosum, aneurysma arteriovenosum) of the lung which have been recorded is still so small that the history, diagnosis, and treatment of such a case are worthy of presentation.

CASE REPORT

H. M. S., a boy, was born Feb. 4, 1937, one month prematurely. He was cyanotic at birth, apparently by strangulation. The cyanosis soon diminished, although the hands remained somewhat blue in color.

At the age of 10 months, the patient developed whooping cough and pneumonia, and in 1939 he had scarlet fever. In July, 1939, on x-ray film, a round, speckled shadow was found in the lower part of the upper lobe of the right lung.

Since the Mantoux reaction was positive, the boy was considered to have tuberculosis and was sent to a sanatorium for one year. Cyanosis at that time was very slight, but there was marked clubbing of the fingers and toes.

During October, 1944, the patient had several hemoptyses, sometimes more than 100 c.c. being expelled. Furthermore, he developed convulsive movements in the left side of the body. At this time he was distinctly cyanosed and over a short period there was a souffle audible at all the valves of the heart, while the heart itself showed some enlargement to the left.

In December, 1944, he suddenly became unconscious. He was very dyspneic and cyanotic, and at the same time coughed up some blood, but in five minutes the condition had improved, although a partial paralysis of the left foot remained.

August, 1945, clubbing of fingers and toes was still obvious. At the back of the neck there was a spot the size of a quarter with telangiectases. The patient had at one time coughed up 300 c.c. of blood. There was no souffle to be heard at the heart or elsewhere in the thorax; the electrocardiogram showed a regular action with a conduction time of 0.15 ventricle 0.07 and negative T_3; no preponderance of right or left. There was also a distinct polycythemia (6,040,000 red blood cells). The circulation time after injection of 2 c.c. magnesium sulfate was 14 seconds.

On the x-ray film of the chest, the same shadow was still visible, now distinctly connected with the hilum by a broad bandlike shadow. Since the shadow on the x-ray film remained unchanged in size and form, the diagnosis of tuberculosis was given up and although at first there had been no signs or symptoms of heart disease the patient was then for several years suspected of having congenital heart disease. However, after some time this diagnosis was reviewed, when we thought that the patient had a cavernous angioma of the lung. This diagnosis was proved correct at operation.

Operation was done April 8, 1947, under endotracheal closed ether anesthesia.* After removal of the seventh right rib, the thorax was opened and in the lower part of the upper lobe of the lung a large number of dark blue tumors could be seen. They projected above the surface of the lung like domes and some of them were as large as a cherry. These tumors were round, very soft on palpation, and pulsated slightly with each heartbeat. They diminished a little in size during inspiration. On compression the tumors disappeared. A very slight thrill could be felt on direct palpation of this part of the lung. The diagnosis of cavernous hemangioma proved to be correct. It was then assumed that there was a very large shunt between arterial and venous systems in the lung and this was proved by the very marked dilatation of the pulmonary artery and vein of this lobe. The symptoms of the patient before operation could all be explained by these findings.

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*Operation by Dr. Boerema, anesthesia by Mrs. Vermeulen-Cranch.

medicine have been done on fit individuals, who were not undergoing a surgical operation. These have shown that there is great individual variation in tolerance for anoxia. The anoxic anoxia produced by 14,000 to 18,000 feet of altitude, which produces an oxygen unsaturation of the arterial blood of 16 to 25 per cent, if maintained for an hour will be harmful to the average healthy individual, and very occasionally will be fatal.[6]

The method used in this investigation was to record continuously the level of arterial oxygen unsaturation during and immediately after major thoracic operations by means of an oximeter. This is an instrument developed by G. A. Millikan[4] which, by means of color filters and a two-channel photocell, gives a continuous recording of the oxygen unsaturation in the blood of the fully dilated capillaries of the ear. Many calibrations against direct determinations of arterial oxygen content are reported in the literature to confirm that the instrument is reliable,[3] and in the present investigation the readings have been checked against determinations of the oxygen content of samples of arterial blood taken during operation, as determined by the Van Slyke technique, and it has proved accurate.

Observations have been made in 70 cases, as follows: pneumonectomy, 12; lobectomy, 27; exploratory thoracotomy, 8; other thoracotomies (for example esophagectomy) 8; thoracoplasty, 15. All these operations have been done under intratracheal ether-oxygen anesthesia, with the exception of the thoracoplasties which were done under intratracheal cyclopropane.

In none of the thoracoplasty cases was there any significant fall in oxygen saturation. However, in the other fifty-five cases, in which the pleural space was opened, the oxygen saturation was subject to surprising swings. Invariably, when the bronchi are sucked out there is an abrupt fall to a level of 25 to 30 per cent oxygen unsaturation, followed by a rise over a period of two to three minutes to the mean level for that patient. This rise to the mean level occurs within ten seconds if positive pressure anesthesia up to 15 mm. of mercury is applied. In addition to these violent swings as the result of suction or positive pressure, there is in many patients, as the operation progresses, a gradually increasing degree of oxygen unsaturation commonly to 8 to 18 per cent, which corresponds to an altitude of 15,000 feet, and occasionally from 18 to 30 per cent. Of the 55 thoracotomy cases studied, the first 5 were discarded because of incomplete data, leaving 50 cases. Of these 24, or 48 per cent, showed no oxygen unsaturation; 11, or 22 per cent, showed 4 to 8 per cent; 11, or 22 per cent, showed 8 to 18 per cent; and 3, or 6 per cent, showed over 18 per cent oxygen unsaturation. One patient developed obstruction of the contralateral main bronchus, which could not be relieved; he rapidly developed oxygen unsaturation of over 45 per cent and a few minutes later died of asphyxia.

This gradually increasing oxygen unsaturation can be prevented or corrected by the application of positive pressure anesthesia at a pressure of 15 mm. of mercury. That this phenomenon is not due merely to inflating the nonfunctioning ipsilateral lung is shown by the fact that the rise occurs even after the bronchus on this side is clamped.

ANOXIA DURING INTRATHORACIC OPERATIONS

A Preliminary Report

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The word anoxia signifies a deficiency in the supply of oxygen available to the cells of the body. The cells which earliest suffer irreparable damage are those of the cerebral cortex, so that in clinical practice it is cerebral anoxia which is significant. A degree of cerebral anoxia sufficient to produce recognizable signs seldom exists after general surgical procedures, but the fact that it can be an important factor in death after major thoracic operations was brought to our attention by three postoperative deaths in a period of two years with clinical and post-mortem evidence of fatal cerebral anoxia.

The signs of severe cerebral anoxia are restlessness, irritability, twitchings, tachycardia, hyperpnea, and rising temperature, leading to coma and death. In a patient who has been subjected to a major operation these may be interpreted as signs of shock, heart failure, or pulmonary atelectasis. At post-mortem the signs are not striking nor characteristic, and may be overlooked. In those patients who survive eighteen hours or more after the onset of the condition there will be cerebral edema.[5] After thirty hours careful histologic study will show changes in the brain,[2] but many patients do not survive that long. It is probable that more deaths have occurred from cerebral anoxia than have been recognized. The picture of "irreversible shock" seen during World War II seems to be identical.

Anoxia is classified as anoxic, anemic, stagnant, or histotoxic. In this investigation we have been concerned with the anoxic type, but it must be borne in mind that during an operation there may be enough blood loss and shock to produce a degree of anemia and stagnation sufficient to contribute appreciably to the total anoxia.

During a thoracotomy the ipsilateral lung is collapsed, and the blood flowing through it, which is not being oxygenated, constitutes a shunt of venous blood to dilute the arterial blood from the functioning contralateral lung. The burden of oxygenation of the blood falls on the contralateral lung and, particularly if it is diseased or has been decreased in volume by a previous lobectomy, anoxic anoxia might be expected to develop. Two of our fatal cases followed lobectomy in patients with bilateral bronchiectasis who had previously had partial resection of the opposite lung.

There is little information available in regard to the degree and duration of anoxia which is likely to be harmful. Investigations carried out in aviation

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This investigation was initiated at the suggestion of Professor Robert M. Janes.
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ANOMALOUS PULMONARY VESSELS

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THE technical advances in thoracic surgery which have made lobectomy and pneumonectomy relatively safe operations have emphasized the clinical importance of anomalies of the vessels supplying the lungs. Prior to these advances in chest surgery, observations on these vessels have been recorded for the most part by anatomists or pathologists. Reference to their occurrence and a classification of the more significant types are lacking in surgical texts and standard anatomic works. Berry,[1] moreover, commented in 1941 on the fact that there is little in the literature regarding the vascular anomalies of the hila of the lungs and urged that they should be reported when encountered. His statement, together with recurring reports of vascular anomalies related to bronchiogenic cysts and experience with three cases of this type, has prompted a review of the problem and the report of these cases with a further case through the courtesy of Dr. Ethan Flagg Butler.

McCotter,[2] in 1910, reported the finding of "an apparently rare case" of a pulmonary artery arising from the thoracic aorta and collected nine cases from the literature. These are summarized in Table I. Batts,[3] in 1939, reported another case and discussed the embryologic aspects. His case, and others reported by nonsurgical workers subsequent to McCotter's review of 1910, are presented in Table II.

Brody,[4] in 1942, reported a case of anomalous pulmonary vein, and summarized 102 such cases previously reported in the literature. Partial drainage of pulmonary veins into the systemic circulation occurred in 68, and of these 74 per cent reached maturity. Compere and Forsyth,[5] discussed this condition and pointed out that the surgeon should be aware of the occurrence of these anomalies.

The first full report of a case of an anomalous pulmonary artery encountered during surgery was that of Harris and Lewis,[6] in 1940. This article also reviewed the comparative anatomy and embryology of accessory pulmonary arteries and veins. Death from hemorrhage occurred in their case. Arce,[7] in 1943, reported a second case in detail. To these reports, four cases are now added. A fatal hemorrhage due to the anomalous vessel occurred in one of these also.

CASE REPORTS

Table III presents the available data on anomalous arteries as reported by surgeons. It includes six instances where brief mention only of the vessel has been made, two reports in personal communications, and the six cases reported in more detail. It would appear that these vessels have been encountered with relative frequency by thoracic surgeons.

Read (by title) at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

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When a patient is under general anesthesia there are no significant changes in respiration, pulse, or blood pressure to indicate a serious degree of anoxia, and cyanosis is a late and unreliable sign.[1] Our anesthetists now watch the oximeter and apply positive pressure as indicated. As a result, in the latter part of the series there have been fewer cases showing anoxia.

A further observation which may be of some importance is that at the termination of operation, when the patient is changed over from breathing the anesthetic mixture with its high oxygen content, to breathing air, there is invariably an increase in the oxygen unsaturation of 6 to 10 per cent. A few cases have been followed for several hours after operation and the level has gradually risen to approximately normal over a period of two hours. The use of an oxygen tent has decreased the oxygen unsaturation by only two per cent.

None of the forty-nine patients who survived operation showed any recognizable evidence of cerebral anoxia in the postoperative period.

To explain these observations it is suggested that during intrathoracic operations there is, in about 50 per cent of cases, a gradual diminution in the efficiency of the contralateral lung due to increasing atelectasis associated with a progressive shift of the mediastinum. This lung is re-expanded and its function restored by the application of a positive pressure of 15 mm. of mercury. The sudden profound fall in arterial oxygen saturation associated with bronchial suction is probably due not only to sucking out oxygen, but also to a temporary increase in the atelectasis by negative intrabronchial pressure. Spasm induced by the irritation of the suction catheter may also be a factor.

From this investigation, to date, it is concluded that with this method of anesthesia a significant degree of anoxic anoxia may occur during major intrathoracic operations, that it is probably due to a progressive atelectasis of the contralateral lung, and that it can be prevented or corrected by the use of positive pressure anesthesia. Since anoxia during operation cannot be recognized by clinical signs, the use of the oximeter is a valuable addition to the technique of major intrathoracic operations. The investigation is being continued.

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TABLE III. ANOMALOUS PULMONARY VESSELS

AUTHOR	YEAR	AGE	SEX	ASSOCIATED PATHOLOGY	VESSEL OF ORIGIN	LOCATION
				Previous Surgical Reports		
Harris and Lewis[6]	1940	5	F	Abscess L L L	Aorta, thoracic	2 cm. above diaphragm
Moore[10]	1940	–	–	Infected cyst L L	Aorta, thoracic	1 cm. above diaphragm
Berry[1]	1941	–	–	R L L	Aorta, thoracic	Below hilum
Haight[11]	1942	–	–	Cyst L L	?	Below diaphragm
Haight	1942	–	–	Cyst L L	?	Below diaphragm
Arce[7]	1943	15	M	Bronchiectasis L L L	?	Through diaphragm, 2 to 3 cm. outside pericardial attachment to central tendon
Brown and Robbins[12]	1944	21	M	Cyst in acc. lobe L L L	Aorta, thoracic	Above diaphragm
Brown and Robbins[12]	1944	51	M	Cyst, bronchogenic L L L	2 large veins	Through diaphragm
Terrell[14]	1944	48	F	Bronchiectasis L L L (secondary to bronchial adenoma)	Aorta, thoracic	
Bugden[15]	1946	26	F	Unresolved pneumonia L L L with suppuration	Aorta, thoracic	Inferior to inf. pulmonary vein; 4 arteries were 7 mm.; 3 were 3 mm. to 2.5 cm. long
				Present Reports		
	1939	15	F	Infected cyst (?) L L L	Aorta	Below diaphragm (?)
	1940	22	F	Abscess of lung L L L	Aorta	Below hilum
	1941	20	F	Congenital cyst L L L	Aorta	Lower border of pulmonary ligament
	1945	13	M	Congenital cyst L L L	Aorta	Between parietal pleura and diaphragm muscle fibers

She was admitted Nov. 4, 1938, x-rays showing "cavity" at the left base posteriorly with fluid level. Open drainage was re-established Nov. 15, 1938, at which time absence of thickened pleura was noted and the correct diagnosis of chronic lung abscess was made. General condition improved but lesion persisted. Lobectomy was therefore done in two stages. On March 30, 1939, the lower lobe was freed and "an anomalous vessel running from either an intercostal artery or the aorta itself was discovered at the lowermost pole. This vessel, approximately 6 mm. in diameter, was isolated but not sectioned at this stage." At Stage 2 on May 9, 1939, the vessel was re-identified. It required suture ligature because of its size. "It contained oxygenated blood—under considerable pressure, and would appear to be an anomalous artery." Lobectomy, completed by mass ligation, was followed by localized empyema and bronchial fistula. Complete healing occurred by July 18, 1939. The patient was discharged, symptomless, on July 29, 1939.

CASE 2 (B. M. H. No. 10399).—C. M.B., aged 22 years, female, white, married. The onset of illness was in 1931, with cough which became productive. Symptoms, relatively mild, recurred at intervals from 1932 to 1938. Sputum then became more copious and late in 1939 became foul. X-ray views on June 17, 1938, showed an ovoid density in the left cardiophrenic angle; on July 7, 1938, fluid level was present.

She was admitted July 11, 1940, roentgenograms showing a sharply outlined area of density 5 by 7 cm. at the left base behind the heart with fluid level present. Lobectomy was done in one stage, July 24, 1940. The left lower lobe was densely adherent in the spinal gutter over an area about 2 cm. in diameter. As the adhesions were cleared, an anomalous vessel was seen projecting from the left wall of the descending aorta to and

TABLE I. SUMMARY OF MCCOTTER'S COLLECTED CASES

REPORTED BY	YEAR	AGE	SIDE	ORIGIN	LEVEL	ACCOMPANYING VEIN
				A. *Anomalous vessels*		
Rektorzik	1861	"Girl"	L	Aorta	10 Dorsal	+
Rokitansky	1861	3 mo.	L	Aorta	10 Dorsal	+ (2 arteries)
Ruge	1878	Newborn	L	7th intercostal	–	–
Humphrey	1885	1 yr.	L	Aorta	–	+
Simpson	1907	Term fetus	R	Aorta	10 Dorsal	–
		B. *Anomalous vessels with accessory lobe*				*Comment*
McCotter[2]	1910	65	R	Aorta	7 cm. above Celiac axis, level of 10 Dorsal	7 mm. artery to right lower lobe
Huber	1777	2 yr.	R	Aorta	7 Dorsal	To right lower lobe
Maugars	1802	7 yr.	R & L	Aorta	Below diaphragm	5 mm. artery branches to right and left lower lobes
Meckel	1820	9 mo.	L	Aorta	1 cm. above diaphragm	9 mm. artery to left lower lobe
Hyrtl	1839	Newborn	L	Aorta	Thoracic	Only vessel to left lower lobe

A review of these cases indicates the occurrence of an associated bronchogenic cyst in a significant proportion. We suggested in 1941 that the relation might be of significance. The accumulating evidence indicates that these solitary bronchiogenic cysts are congenital in origin and that they are frequently accompanied by anomalous arteries which are almost entirely congenital in origin also.

The two most significant types of anomalous arteries appear to be (1) those arising from the aorta and passing laterally to the lung. This is the type described by McCotter. It is possible that these are related to the artery described by Turner,[13] which is not infrequently found traversing the pulmonary ligament and giving an arterial supply from aorta to lung. (2) The other group of arteries arise lower down either at or just below the level of the diaphragm. They are of the type described by Batts. These are particularly hazardous from the standpoint of surgical approach.

TABLE II. ANOMALOUS VESSELS—PATHOLOGIC REPORTS

REPORTED BY	YEAR	AGE	SIDE	ORIGIN	COMMENT
Batts, M. J.[3]	1939	40	R	Celiac axis	To right lower lobe
Park[8]	1912	–	R	Right phrenic artery	Base of right lung
Doering[9]	1914	–	R	Innominate artery	Anomalous origin of the right pulmonary artery
Menke[6]	1936	60	R	Right subclavian	Followed right bronchus

It would appear that emphasis should be placed on the possibility of encountering anomalous vessels when surgical extirpation is being carried out of a lesion which falls within the category of bronchiogenic cysts.

CASE 1 (B. M. H. No. 5371).—D. M. D., aged 15 years, female, white, single. The onset of illness was in 1926, when she was treated for "chronic empyema" by open drainage with subsequent healing of the tract. She thereafter remained under observation, roentgenograms showing a persistent rarefied area at the left base; cough continued but was moderate. In 1937 symptoms increased, sputum "tasted bad," and cough was severe.

attack the basal adhesions when all other structures had been separated. This could be easily done, and finally the lobe was free except for these dense adhesions. The pleural cavity had been entered through the seventh interspace, and the adhesions were at the level of the tenth interspace or lower. It was difficult to obtain free and unobstructed visibility of the adherent area. The dissection was proceeding slowly, partly by blunt dissection, partly by scissors dissection, when there was sudden severe and uncontrollable hemorrhage. In spite of all efforts it was impossible to prevent a fatal outcome.

After the death of the patient it was possible to identify a branch from the aorta arising just below the reflection of the pleura from posterior mediastinum to diaphragm, and just above the fibers of the diaphragm. This branch was about 5 mm. in diameter. It was very short and had obviously been under traction at the time that it had been cut. It must have immediately retracted into the depths of the field, and the stump was too short to grasp.

Comment.—The tragic outcome in this case would probably have been avoided if adequate exposure of the anomalous vessel had been obtained through a lower interspace. This experience emphasizes the necessity of being on guard for congenital vascular anomalies when face to face with even presumptive congenital structural anomalies.

SUMMARY

1. The surgical importance of anomalous pulmonary vessels is apparent.

2. Reports relating to anomalous pulmonary arteries and veins in the anatomic and pathologic literature are tabulated.

3. Four cases encountered during operation are reported.

4. Ten cases previously reported by surgeons are summarized.

5. Two types of anomalous pulmonary arteries are reported by both pathologists and surgeons, the more common type rising from the aorta below the hilum, the second arising from the abdominal aorta or celiac axis.

6. In the pathologists' material anomalies are approximately equally distributed between the right and left sides.

7. In the surgical cases the vessel was on the left side in ten, on the right in one, and the side was not specified in three. The associated pulmonary pathology was an infected cyst in eight instances, a fact which suggests that multiple congenital anomalies were present.

The author wishes to express his indebtedness to Dr. E. F. Butler for his interest and stimulating suggestions, since the first case was encountered on his service in Ithaca in 1939.

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into the substance of the left lower lobe. This anomalous vessel was about 1 cm. long between the aorta and the branches which spread into the left lower lobe substance. The diameter was about 4 mm. The vessel was doubly ligated and sectioned. Lobectomy was completed by individual ligation. A localized empyema developed and was drained. Healing occurred October 10. The patient was discharged Oct. 12, 1940, free from cough and expectoration.

The pathologist reported that the anomalous vessel entering the lower part of the lobe could be traced by means of serial cuts—and extended inferior to the main abscess cavity, branching out into finer radicles toward the hilum.

CASE 3 (B. M. H. No. 11184).—M. E. J., aged 20 years, female, white, single. The onset of illness was in January, 1938, with lassitude. Productive cough began August, 1939, followed by twelve pound weight loss. X-ray studies August, 1939, revealed bronchiectasis and possibly pulmonary cyst. Surgical treatment was refused by the patient at this time. Persistent productive cough subsequently caused her to accept operation.

She was admitted Jan. 20, 1941, x-ray views suggesting abscess of left lower lobe with fluid level. Lobectomy in one stage by individual ligation technique was done Feb. 12, 1941. At the very lower end of the pulmonary ligament an anomalous artery approximately 4 mm. in diameter, arising from the descending aorta, entered the substance of the left lower lobe. After this artery had been ligated and sectioned, the left lower lobe could be easily delivered. The postoperative course was uneventful and the patient was discharged on March 14, 1941.

X-ray films were made of the excised lobe before and after instillation of skiodan in the anomalous vessel. The distribution is related to the area of cyst.

The pathologist described the stump of a relatively thick-walled vessel 0.7 cm. in diameter situated medially and posteriorly about 2 cm. above the diaphragmatic border. This vessel was seen on section to travel with branching anteriorly and posteriorly skirting the borders of a large excavated area. A section of the vessel stained for elastic tissue showed a very distinct internal elastic layer which in places presented fine undulations. In the media there was a considerable amount of elastic tissue. The changes in the lung parenchyma strongly suggested congenital cystic disease.

CASE 4 (A. O. M. H. No. 26719).—R. B., male, 13 years of age, white, schoolboy. The patient had had "asthmatic symptoms" since childhood. There had been four attacks of "pneumonia," the first in May, 1938, and the others at approximately two-year intervals. In 1939 the condition was diagnosed "congenital cysts of the left lower lobe" with associated bronchitis and chronic asthma. Previous studies had demonstrated at least fourteen cystic pockets in the left lower lobe, sometimes with, sometimes without fluid levels. Never had there been any evidence of pathologic processes involving the left upper lobe or any portion of the right lung. The boy lived as a semi-invalid because of dyspnea and other "asthmatic symptoms." Nutrition, however, was maintained at a satisfactory level.

The patient had been admitted to the Arnot-Ogden Memorial Hospital (Elmira) from time to time for diagnostic study or medical treatment. He was admitted for definitive surgery on March 25, 1945. Three days later, the general condition being satisfactory, a left lower lobectomy was undertaken. At operation the findings were reported as follows: On opening the left pleural cavity, the left upper lobe was free and quite normal in appearance and texture. The left lower lobe was irregular with ballon-like, bluish, cystic areas interspersed through apparently normal lung tissue. The left lower lobe was everywhere free of adhesions except over the diaphragm and at the lowermost posterior border where it was densely adherent into the sulcus between diaphragm and chest wall, in the spinal gutter. It later developed that the anomalous artery lay at this point. It was about 5 mm. in diameter, and it opened directly from the lowermost thoracic aorta, definitely above the diaphragm but below the pleural reflection. In other respects the hilar structures were normal in their anatomic pattern, and the fissure between the upper and lower lobes was reasonably well developed.

The unusual adhesions at the left base created a problem that required special handling. Inasmuch as the anatomic structures in the pedicle of the lobe were easily accessible, it was decided to carry out all the steps of lobectomy by individual ligation technique and then

TABLE I. CASES OF ECTOPIA CORDIS REPORTED

Author	Number
1. Collected by Blatt and Zeldes	53 (with case report)
2. Collected by Roth (excluding 33 cases also reported by above)	83
3. Hofmann (1938) Puddu & Cammarella (1938) Kuhnel (1940) Sosyal (1940) George (1945)	5
4. Present case report	1
Total	142

thirteen months (Greig).[8] The longest duration of life in the infants with combined thoracoabdominal hearts was *four months.* With the exception of Greig's case all of the infants who survived more than one year had abdominal hearts. The most striking case was that reported by Deschamps who described an autopsy on an old soldier who had died of suppurative nephritis. The left kidney was found to be absent and in its place was the heart within its pericardial sac. The vessels passed through a small hole in the diaphragm. Epigastric ectopia also is not incompatible with life as a number of case reports describe patients in whom an epigastric heart could be grasped in the hand. Two patients were seen when pregnant. One patient was said to be apparently well at the age of 75 years.

Many of the cases had associated congenital anomalies. As might be expected, most of these associated anomalies were cardiac. Greig, in reporting 38 cases from the literature, stated that 2 patients had trilocular hearts, 3 had bilocular hearts, 6 had two superior venae cavae, and 4 had multiple anomalies.

In those cases in which electrocardiographic tracings have been obtained the findings have not been striking. Lintgen[9] reported only slight variation in rhythm. Puddu and Cammarella[4] carried out extensive studies to determine the direction and speed of the electrical impulses at various points on the atria and ventricles. These studies served to corroborate the accepted findings in animal experimentation and confirmed the studies of Barker, Macleod, and Alexander.[13] Barlow[10] felt that the studies in his case tended to disprove the blood vessel theory of conductivity but his tracings revealed some inconsistency. In making tracings with the conventional leads no deflections were noted, indicating that there was no difference in potential between the two halves of the body. When, however, tracings were obtained from electrodes on the surface of the heart and the extremities there was a much greater deflection with the electrode on the right leg than when it was placed on the left. This is difficult to under-

TABLE II. DISTRIBUTION BY SITE OF DEFECT

Site	Number
Thoracic	81
Abdominal	38
Combined thoracoabdominal	10
Cervical	4
Unclassified	9
Total	142

ECTOPIA CORDIS

REPORT OF A CASE WITH ATTEMPTED OPERATIVE CORRECTION

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THE term "ectopia cordis" has been used to describe all anomalies in which the heart is not within the thoracic cage. Although the congenital defect is a rare one I have found 141 cases in the literature, probably because the anomaly is such a startling one that most of the cases that have occurred have been reported. As far as I have been able to determine only five attempts have been made at surgical correction of this lesion and it is for this reason that this case report is made.

The first description of the anomaly is variously ascribed to Haller or to Martinez, both reporting cases in 1706. Weese, in 1818, was apparently the first to attempt an anatomic classification of the lesion and used the terms (1) ectopia cordis cum sterni fissura, (2) ectopia cordis suprathoracica, and (3) ectopia cordis subthoracica. Townsend, in 1833, preferred the terms (1) cervical heart, (2) pectoral heart with fissure of the sternum, and (3) abdominal heart with a defect in the diaphragm. Perhaps a fourth type, the combined thoracic and abdominal, should be added.

Blatt and Zeldes[1] reviewed the literature in 1942 and found reports of 52 cases, occurring between 1706 and 1938. Roth,[2] in a collective review published in 1939, was able to find record of 83 cases in addition to those listed by Blatt and Zeldes. In addition to the case reported here, I found five additional case reports, making a total of 142 cases.

The location of the ectopia was, in 9 cases collected by Roth,[2] not accurately described so that exact classification was not possible. Of the remaining 133 cases, the site of the defect is shown in Table II.

Of the 52 cases collected by Blatt and Zeldes,[1] 19 infants were premature, 16 were full term, and in 17 the period of gestation was not reported. Of these, 11 were stillborn, 13 lived less than twenty-four hours, 11 lived one to seven days, 3 lived eight to thirty days, 3 lived one to two months, and 8 lived one year or more. Duration of life in 3 was not reported. The life expectancy varies considerably with the site of the ectopia and with the presence of associated abnormalities. Many possessed no covering for the heart, the myocardium being exposed, as in the case here reported; in others a pericardial sac was present and in some skin was also present over the defect in the thoracic wall. In several of the abdominal ectopias no defect was visible.

The prognosis is poorest in the cervical site. Of two cases reported one infant was stillborn and one lived a few hours. Of 30 with thoracic ectopia 5 were stillborn. The remainder lived from one hour to sixteen days. One lived

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From the Department of Surgery, University of Michigan Hospital.

Read (by title) at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

stand in view of the failure to obtain deflections in the conventional leads which would indicate a lack of potential between the two extremities. The tracings obtained by Blatt and Zeldes were not strikingly abnormal. In our case the findings were without value as they were taken with a moist saline pad on the heart.

CASE REPORT

Baby Girl S. was referred to the University of Michigan Hospital for surgical correction of an external heart and was admitted eighteen hours after delivery. The period of gestation had been normal with the exception of hyperemesis gravidarum during the first six months. The mother had had no previous pregnancies. The delivery was described as normal. Upon admission the temperature was 98.4 degrees, the hemoglobin 15.4 Gm., and the leucocyte count 19,600.

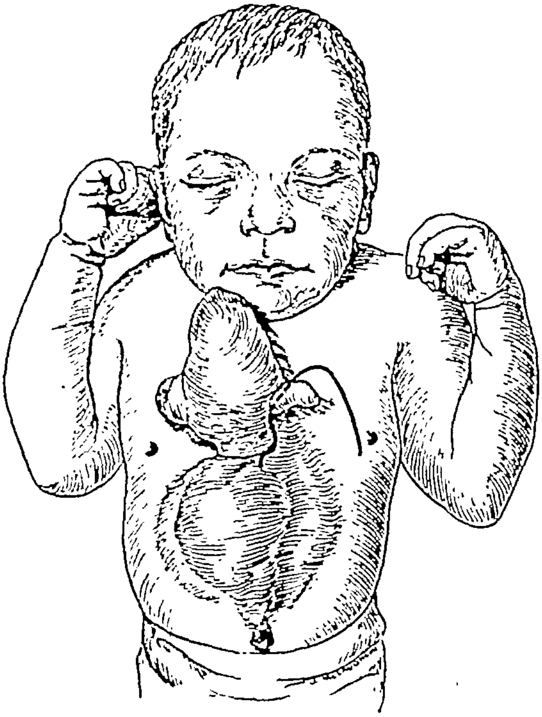

Fig. 4.—The heavy line represents the incision used to form a skin flap and gain access to the left pleural cavity.

The physical examination was not remarkable save for the evident anomalies. The manubrium was present but the sternum was totally absent. The heart was completely external and uncovered by any membrane, the myocardium being exposed. It was vertical in position with the apex, which was bifid, pointing straight up and, at times, beating against the infant's chin. The heart surface dried readily and had to be kept moistened. The blood flow through the coronary artery, which was single, the right coronary artery being absent, could readily be seen. The atria consisted of short cylindrical appendages which shortened upon contraction but decreased little in caliber. The right ventricle seemed larger than the left. The great vessels entered the heart through a 2.5 cm. opening just inferior to the lower border of the manubrium. The vena cavae, the aorta, and the pulmonary artery could be distinguished. The skin below this opening was absent and in its place was an irregular area of grayish gelatinous-appearing tissue which extended down to the umbilicus. This area had roughly the shape of the heart when it was placed against the body. The prominence of the

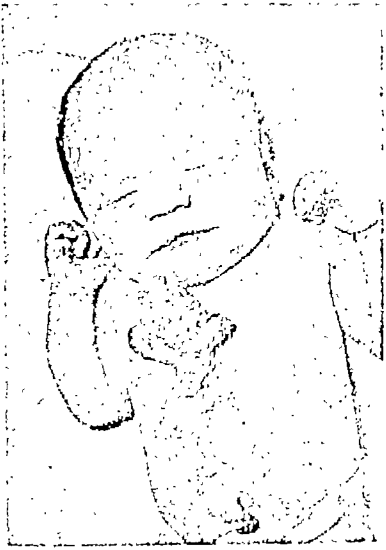

Fig. 1.

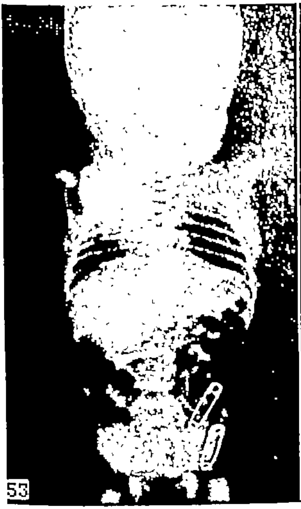

Fig. 2.

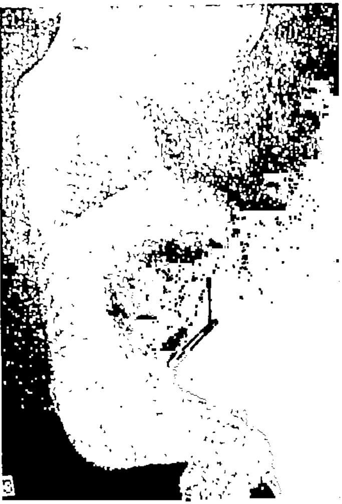

Fig. 3.

subjected to operation by other authors, correction of the defect does not appear to be feasible.

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NOTICE

The twenty-ninth annual meeting of the American Association for Thoracic Surgery will be held on March 29, 30, and 31, 1949, in New Orleans, La. Headquarters will be at the Roosevelt Hotel.

Requests for hotel reservations should be mailed direct to Dr. Alton Ochsner, 1430 Tulane Avenue, New Orleans 13, La.

Abstracts for presentation of papers for the 1949 meeting must be received for consideration by the Program Committee, on or before Jan. 1, 1949. These abstracts should be submitted in *quadruplicate* and addressed to the Secretary of the Association, Dr. Brian Blades, George Washington University Hospital, 901 23rd St., N.W., Washington 7, D. C. They should not be sent to the Editor. The early date of the 1949 meeting makes it absolutely necessary that these abstracts be received before the deadline date. Abstracts received after Jan. 1, 1949, will not be considered.

Manuscripts for competition in the Rose Lampert Graff Prize should be sent directly to the Secretary of the Association not later than Jan. 1, 1949.

upper abdomen was striking and it appeared that this prominence was due to the protrusion of the liver beneath the weakened abdominal wall.

A motion picture, in color, of the functioning heart was obtained. The x-ray views revealed the absence of an intrathoracic heart.

It was explained to the child's father that operation offered little chance of correcting the defect but he was extremely anxious to have an attempt made. From an operative standpoint a number of difficulties presented themselves. First, the absence of normal skin inferior to the heart made placement of an incision difficult; second, it was probable that the heart would not tolerate displacement from the vertical position; and third, there seemed to be no place to put the heart.

Under ether anesthesia an incision was made horizontally from the opening in the midline and carried down vertically toward the left nipple. The skin and subcutaneous tissue was then undermined to the common cartilages, giving exposure almost to the midline. The pleura was thus exposed and the absence of a pericardial sac verified. The only way to place the heart beneath the skin flap was to place it within the left pleural cavity and this was done. However, the cardiac beat became very weak when this maneuver was carried out and accordingly it was returned to its original position. Another attempt was made but again the beat became feeble. Since further procedure seemed fruitless the chest was closed under slight positive pressure and the skin resutured. At the conclusion of the operation the cardiac beat was exceedingly feeble and failed to respond to the intracardiac injection of adrenalin. Death occurred approximately twenty-two hours after birth.

The post-mortem examination revealed a tetralogy of Fallot. There was hypoplasia of the pulmonary conus and aplasia of the root of the pulmonary artery, a widely patent ductus arteriosus, an interventricular septal defect, and a large patent foramen ovale. Only the left coronary artery was present. There were also an incomplete descent of the cecum and abdominal ascites.

DISCUSSION

Previous attempts at operative correction have been made by Cutler and Wilens,[11] Bloch,[12] and Hofmann.[3] I have learned that E. Finocchietto also attempted the operation but did not report the case. In Bloch's case the child lived seven days after the heart was placed beneath skin flaps but its action was impaired and the sutures had to be removed. In Hofmann's case the baby died during an attempt to place the heart beneath the skin. Cutler and Wilens made an oblique incision downward from the ring and exposed the pleura. As in my case, the prominence of the liver prevented the creation of an adequate pocket for reception of the heart. When the defect was nearly closed by approximating the skin flaps, the heart was throttled by the tension. Recognizing the futility of further attempts they removed the sutures. The child lived eleven hours after operation. The operative findings in each case have been similar and it would appear the corrective attempts are not justified.

The absence of normal skin below the defect in the chest has been present in many of the cases. The best explanation of this is put forth by Barlow. Since, in this case, this skin defect was roughly the shape of the heart when it was forced against the chest wall he felt that the constant pressure and irritation of the beating heart during uterine life was the cause.

SUMMARY

A case of ectopia cordis with an attempt at operative correction is presented. On the basis of the operative findings in this case and in the four other cases tion necessary to establish the validity of conclusions on the efficacy of any therapeutic procedure used in the treatment of pulmonary tuberculosis, we recognize that the period of postoperative observation in our present case material is much too short. We therefore wish to present it only as a preliminary report to be followed, we hope, by a more thorough analysis when our series of cases has increased, and an adequate postoperative observation period has passed.

All who have had experience with pneumothorax therapy for pulmonary tuberculosis encounter cases in which, after a successful pneumothorax has been maintained for the optimal time, the lung will not re-expand after pneumothorax refills have been abandoned. The percentage incidence of this complication is probably not large. However, reliable figures as to its frequency seem to be lacking in the literature. Farber[2] stated that in a limited experience roughly 5 per cent of cases of therapeutic pneumothorax terminate in unexpandable lungs. He reported the occurrence of 27 cases in 318 patients receiving pneumothorax treatment from July, 1939, to July, 1941, and emphasized its significance as a clinical problem. John Alexander[6] discussed it as an indication for thoracoplasty. He gave as causes of the failure of the lung to expand:

1. Extensive destruction and fibrous contraction of a greater part of the lung.
2. A rigid, thick visceral pleural that is often the result of a pleural effusion or empyema.
3. Stenosis of the large bronchi with resultant atelectasis.

The inability of a lung to expand after the abandonment of pneumothorax refills usually results in (1) highly negative intrapleural pressures due to absorption of some of the pneumothorax air. Clinically this may produce a disagreeable sensation of tension, dyspnea, and sometimes a pleural effusion, which recurs frequently following repeated thoracenteses (*Collapsus imperatifs of Veran*). (2) The drawing toward the chest wall of the collapsed lung together with the mediastinum and its structures, the trachea, heart, and great vessels. As a consequence the opposite lung may become overdistended and emphysematous, and latent tuberculous foci may be opened. The vital capacity may be actually decreased. Farber[2, 3, 4] pointed out the dangers inherent in the "dead pleural space" as "chiefly empyema, tuberculous or mixed infection, and broncho-pleural fistula."

The remedial measures applicable to this situation have in the past been: (a) Indefinite continuation of therapeutic pneumothorax, (b) substitution of oleothorax for pneumothorax, (c) thoracoplasty.

In relation to the causes of nonexpandibility enumerated by Alexander[6]: the first, extensive parenchymal lung destruction and fibrosis and the third, bronchostenosis and atelectasis, would still call for thoracoplasty. Both must be given adequate consideration in planning any therapeutic approach. Judgment as to the extent of lung destruction and fibrosis will depend in large measure on the appearance of the entire series of x-ray films and the appearance of the collapsed lung at the time re-expansion is contemplated. Bronchostenosis as a cause of nonexpandability can be ruled out by bronchoscopy. Very often bronchoscopy of a collapsed lung will reveal a slit-like narrowing of the main or

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Original Communications

DECORTICATION OF THE NONEXPANDABLE POSTPNEUMOTHORAX TUBERCULOUS LUNG

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EXPERIENCE of army surgeons during World War II with the development of pulmonary decortication in the treatment of fibrosing traumatic hemothorax, both with and without infection, has awakened interest in the possible applicability of this valuable procedure to some of the problems still unsolved in the surgical treatment of pulmonary tuberculosis.

Sampson and Burford[1] in their recent article on "Total Pulmonary Decortication," speculated on the possible applicability of early decortication in the treatment of acute or subacute total tuberculous empyema. There are sporadic references in the older literature to attempts at decortication in the treatment of tuberculous empyema. Apparently the failure of the then used techniques, plus the hazards and complications have prevented this procedure from becoming a popular therapeutic measure for this indication.

At the Twenty-sixth Annual Meeting of the American Association for Thoracic Surgery, May, 1946, a paper was read by Dr. Frazer B. Gurd on "Decortication in Tuberculous Empyema." In the discussion of that paper one of us (D. M.) presented a brief résumé of one of the case reports which make up the basis of this present paper.

We wish to present the case material herewith as the early results of an attempt to apply the basic principles of pulmonary decortication to the problem of the postpneumothorax nonexpandable tuberculous lung. We have not found reference in the literature to the use of decortication for this indication up to the time of preparation of this paper.

Fully realizing the chronicity of the nature of tuberculosis, the proneness to recurrence and exacerbation, and the long period of postoperative observa-

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Read (by title) at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery at St. Louis, Mo., May 28, 29, and 30, 1947.

In the light of this described pathology, the feasibility of decortication in some of these nonexpandable cases must be admitted, and has been proved in the cases presented herewith. Even in cases that have a favorable roentgenologic appearance, it is usually quite impossible to foretell preoperatively whether or not a satisfactory decortication can be accomplished. This calls for exploratory thoracotomy, which with modern techniques and skillful anesthesia does not usually entail any serious consequences or complications to the patient even in the presence of an open lesion on the opposite side. Preoperative thoracoscopy has been tried, but as one usually sees only a space lined with glistening hyalinized fibrin, and is unable to visualize the lung or lobar outlines, or in fact any distinguishing anatomic landmarks, we have not found it of very much value.

As for indications we are forced to depend so far on the theoretical deductions in which we assume that decortication and resultant re-expansion of the collapsed lung would be of benefit to the patient. Until our series of cases is larger we cannot define or limit the indications more clearly. We have set up tentatively the following list of possible indications:

1. To increase functional respiratory capacity when it is required to permit major collapsing procedure or resection for an open lesion on the contralateral side.
2. To avoid extensive thoracoplasty for the obliteration of the pleural dead space.
    (a) When pleural effusion is persistent or recurrent on attempted re-expansion. *(Collapsus imperatifs of Veran.)*
    (b) When a secondary pyogenic non-tuberculous empyema is present.
    (c) When attempted re-expansion is resulting in the shifting of the heart and mediastinum toward the chest wall, and creating overdistention dangerous to the opposite side.
3. Nonexpandability in the face of patient's desire to abandon pneumothorax, and avoid indefinite refills.

We have not included in our indications as yet tuberculous or tuberculous-pyogenic empyema, preferring for the present to observe our results in theoretically less hazardous cases. We have also so far avoided attempting decortication in any case which had a definite history of tuberculous empyema, or a pleural fluid positive for tubercle bacilli at any time during the course of pneumothorax treatments, even though presently dry or negative for these organisms.

The question arises as to the danger of subsequent reactivation of the old tuberculous focus or reopening of the cavity by the rapid re-expansion following decortication as compared with the more leisurely controlled re-expansion under fluoroscopic observation usually followed in readily re-expandable lungs on abandonment of pneumothorax. Only long-time observation on a large series of cases will determine the percentage expectancy of this eventuality. So far in our series we have attempted to obtain maximum re-expansion as soon branch bronchi. This condition is mechanical and is due to compression or angulation of the bronchus and it is not a hindrance to expansion. It should not be confused with concentric cicatricial stenosis due to previous inflammatory pathology of the bronchial mucosa, which may be a definite hindrance to re-expansion.

It is with the second cause of nonexpandability cited by Alexander[6] that we are concerned here, that is, the so-called rigid, thick visceral pleura. Farber,[2, 3, 4] in summarizing the causes of nonexpandability stated, "The important factors in preventing re-expansion seem to be visceral pleural thickening (pachy-pleuritis) and extensive post-tuberculosis parenchymal fibrosis." We believe that this concept of a pachy-pleuritis, or thickening and fibrosis of the visceral pleura, is in at least a great many of these cases a pathologically erroneous one. It had often been noted at postmortem examination of patients dying while under pneumothorax treatments that the hyalinized fibrous envelope which encased the collapsed lung could be readily peeled away from the visceral pleura, leaving the latter intact and fairly normal in appearance except for small areas here and there, especially overlying the most diseased portion of the lung parenchyma, where the underlying parenchymal inflammation had penetrated the visceral pleura and caused it to become intimately adherent to the envelope. With the advent of resection surgery for pulmonary tuberculosis, this condition was again noted in mobilizing a lung or lobe prior to resection, if an unsatisfactory pneumothorax of some duration preceded the indication for resection.

The pathology then is not always inflammatory thickening of the visceral pleura itself, although that undoubtedly does sometimes occur particularly if the pneumothorax has been complicated by a true bacillary tuberculous effusion. Not uncommonly it consists of the laying down of a hyalinized fibrous layer on the pleura (Figs. 9 and 10) to which it is not intimately adherent in large part, but attached by a thin areolar vascularized layer (Figs. 10 and 11) which may be easily separated by blunt dissection, leaving behind an intact and, for the most part, fairly normal and expandable visceral pleura. This fibrous envelope (Figs. 5, 9, 10, and 14) may vary from a thin transparent pliofilm-like layer to a thickness of 1/4 inch or more, but regardless of thickness the character of the loose areolar layer (Figs. 10 and 11) approximating the pleura is the same.

This fibrous envelope is in all respects similar to that described by Delorme,[7, 8, 9] Lilienthal,[10, 11] and others in the older literature as being the underlying pathology in nonobliterating chronic postpneumonic pyogenic empyema, which permitted decortication and re-expansion in these cases, and more recently by Langston and Tuttle,[12] and Sampson and Burford[1] in their work on decortication for organizing hemothorax and posttraumatic empyema. The concept that the membrane which limited lung expansion was always due to inflammatory fibrosis of the pleura itself was proved erroneous in the case of tuberculous empyema by Delorme, and in the case of pyogenic empyema by Lilienthal, and was discussed by Sampson and Burford.[1]

weeks. We are not prepared to comment on its efficacy, but will undoubtedly use it more freely in the future. We had planned to use it if cases showed any signs of fresh activation or tuberculous empyema following operation.

ANESTHESIA

We consider intratracheal anesthesia mandatory, and prefer ether-oxygen as the anesthetic of choice. At the end of operation the trachea is cleared by catheter suction through the intratracheal tube. If there is any indication that the bronchial tree is not perfectly dry, or that there are retained secretions or bronchial plugging, immediate bronchoscopic suction is done. This is repeated at any time during the immediate postoperative course, if atelectasis or retained bronchial secretions supervene.

OPERATION

It is unnecessary to give a detailed description of the operative technique as this has recently been so adequately done by Langston, Tuttle, and Crowley,[13] and by Sampson and Burford[1] in their descriptions of pulmonary decortication for organizing hemothorax. Our choice of approach has been through a posterolateral thoracotomy incision with resection of the fifth or sixth rib. The technique of the decortication is the same as described by these authors with this exception: in tuberculous cases when one approaches the diseased or former cavity-bearing area, one often finds that at this point the fibrous envelope is intimately adherent to the underlying lung, and at times shows evidence of tuberculous involvment. When this condition is encountered, the encasing plaque is separated from all directions toward the adherent area as far as easy separation is possible. The plaque is then cut around the adherent area leaving this adherent button attached to the underlying lung. In this way traumatizing the diseased portion of the lung and the danger of opening up old tuberculous foci are avoided. We should like also to emphasize the insistence of these authors on the complete freeing of the decorticated lung from all adhesions to the diaphragm and mediastinum, the freeing of the interlobar fissures, and the freeing of all adhesions on the visceral pleural surface which are causing enfolding or distortion of the lobe. In tuberculous lungs this freeing is, of course, carried out only over the more normal undiseased portions of the lung, and scarring over the diseased portion is not disturbed. At the end of decortication and freeing of adhesions the lung is gently and slowly re-expanded by intratracheal positive pressure to see that maximum expandability, especially of the more normal portions, is obtained. To maintain the expansion and drain postoperative effusion, two No. 45 French right angled latex suprapubic drainage tubes are placed into the pleural cavity through stab wounds in the third anterior and eighth posterior interspaces. If good expansion has been obtained and there is a minimum of residual pleural fluid as checked by x-ray these tubes are removed in forty-eight to seventy-two hours. During operation fluid is administered continuously through a cannulated leg vein using 5 per cent glucose in saline, and whole blood as indicated. Sufficient whole blood is given during and immediately following operation to replace all blood loss and restore a normal hemoglobin and hematocrit reading. Penicillin, 100,000 units in 20 c.c. of solution, is placed in the pleural cavity before closure of the operative wound.

POSTOPERATIVE CARE

Oxygen is administered for forty-eight to seventy-two hours postoperatively by oxygen tent or intranasal catheter. If the vital signs are normal and there are no contraindications, patients are permitted out of bed following removal of the expansion tubes from the pleural cavity. Deep breathing exercises are also started on this day, unless contraindicated by pathology in the opposite lung. Fluids by mouth are started postnausea, and regular diet resumed as tolerated.

CASE REPORTS

CASE 1.—M. S., a 30-year-old white woman, a nurse, was admitted to St. Vincent's Hospital Jan. 30, 1946, with temperature of 103° F. and complaint of pain in the left side of as possible postoperatively by means of an anterior upper, and posterior lower No. 45 French intrapleural tube connected with water-trapped drainage bottles. These tubes are usually removed in forty-eight to seventy-two hours. We have considered the possibility of maintaining a pneumothorax after decortication, and permitting a controlled re-expansion with a view to avoiding reactivation. However, it seemed that the ever-present danger of reopening old tuberculous foci on the pleural surface in the course of decortication demanded as rapid as possible obliteration of the pleural space for the prevention of a more serious complication, tuberculous empyema. So far we have no cause to regret this course of procedure, because none of our cases have developed a tuberculous empyema, or had persistent pleural fluid, although we have at least three times in the course of decortications opened into old tuberculous foci on the pleural surface. Neither have any of our cases to date had any reopening of the old cavities or reactivated lesions in the re-expanded lungs. We have noted under direct observation at the operating table after completion of decortication that the previous site of cavitation and maximum disease, due to parenchymal fibrosis and scarring of the visceral pleura in that area, does not re-expand well even with intratracheal positive pressure. The obliteration of the pleural space is accomplished by normal undiseased portions of the lung which push the fibrosed nonexpanding portion into the dome of the thorax or the costo-vertebral gutter. This has been further borne out by the postoperative roentgenograms which show the previous cavity-bearing area unexpanded.

In cases where decortication is indicated, and in which the duration of pneumothorax is not deemed sufficient to achieve healing of the original lesion, or where the roentgenograms indicate some danger of reactivating an old cavity, we have contemplated doing a partial decortication and re-expansion of the nondiseased portion of the lung, for instance an entire lower lobe, and leaving the diseased portion collapsed and encased in its limiting envelope. Then following maximum expansion of the nondiseased portion, a limited thoracoplasty would suffice to obliterate any residual pleural dead space. We have not yet encountered a suitable case for this procedure.

PREOPERATIVE PREPARATION

As the operation is elective and usually nonurgent, time and effort are not spared to bring the patient to operation in the best possible condition physically and physiologically. Attention is given to obtaining normal hemoglobin and red blood cell levels, normal blood protein, and augmented intake of vitamins. Bronchoscopy should be done on the patients to rule out active tracheobronchial tuberculosis, and cicatricial bronchostenosis. Vital capacity determinations should be made, and respiratory functional studies of both lungs by bronchospirometry are valuable and should be done if facilities are available. Thoracoscopy has been done on some patients, but as mentioned previously, does not seem to contribute a great deal of helpful information. Penicillin in dosage of 25,000 units every three hours is administered for forty-eight to seventy-two hours preoperatively and is continued postoperatively in increased dosage of 50,000 units every three hours until the vital signs have remained normal for forty-eight to seventy-two hours. Streptomycin has not been used routinely preoperatively in our cases to date. In Case 5 it was given for one week preoperatively in dosage of 1 Gm. per day, and continued for four weeks postoperatively at the same dosage level. In Case 4 it was given postoperatively in dosage of 1 Gm. per day for four

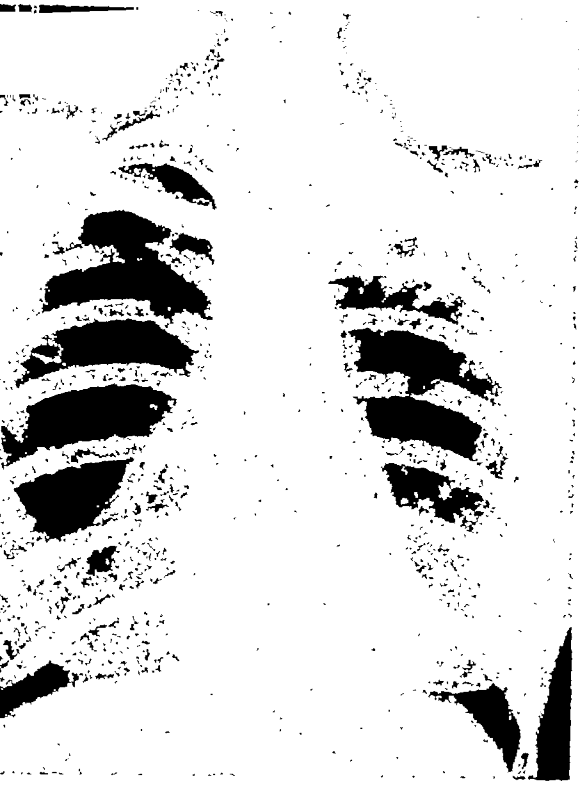

Fig. 1.

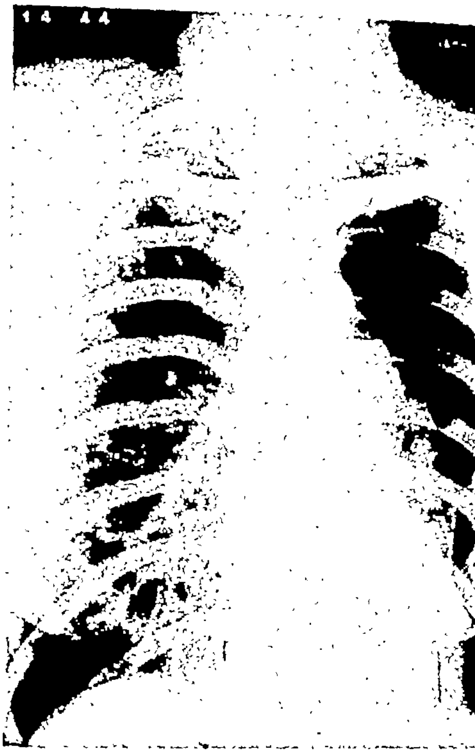

Fig. 2.

Fig. 1 (Case 1).—Original tuberculous lesion, 1938. Caseous-pneumonic process with cavitation in left upper lobe.

Fig. 2 (Case 1).—Status during pneumonthorax treatment, 1939 to 1945. Well-collapsed lung with fibrosis of upper lobe lesion. No pleural fluid.

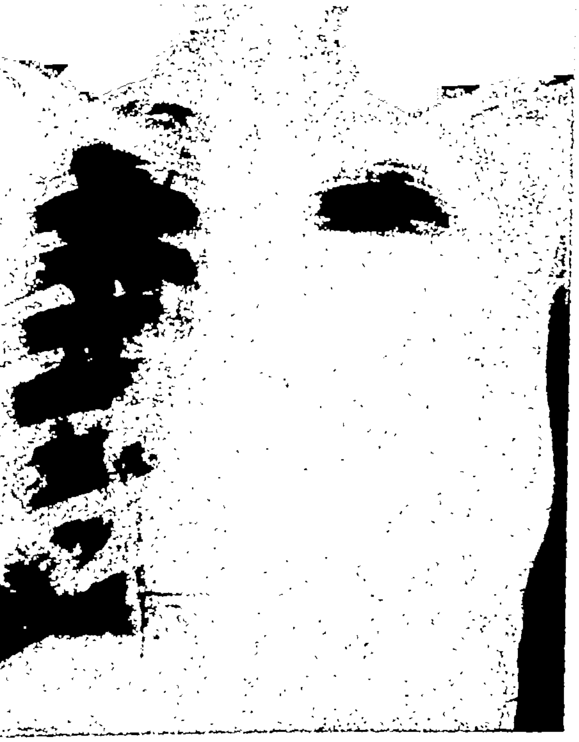

Fig. 3.

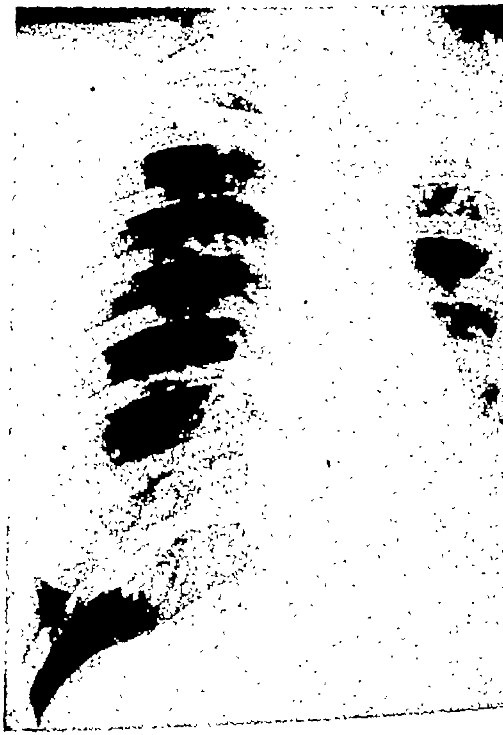

Fig. 4.

Fig. 3 (Case 1).—March 26, 1946, hydropneumothorax. Nonexpandable collapsed lung not visible. Before left decortication.

Fig. 4 (Case 1).—April 1, 1947, ten months after decortication and re-expansion of left lung. Pneumothorax space completely obliterated. Lung well expanded. Note supra-apical organized fibrous cap and unexpanded fibrotic lung at site of original lesion.

the chest, dyspnea, and nausea. X-ray examination revealed left hydropneumothorax with fluid to the level of the sixth posterior rib. No aerated lung was visible on the left side. Right lung showed no pathology.

Past History.—The patient had entered the hospital in August, 1938, with the complaint of unproductive cough of five weeks' duration, loss of weight, and fatigue. X-ray views revealed a tuberculosis infiltration of the left apical region with a 2 cm. cavity, and sputum was positive for tuberculosis. She was transferred to a sanatorium where artificial pneumothorax was induced and a closed intrapleural pneumonolysis for apical adhesions was done. An excellent collapse was obtained, and sputum conversion followed shortly. She was discharged from the sanatorium in the summer of 1939 to continue pneumothorax treatment at home as an ambulatory case. She resumed work as a nurse about January, 1940, and continued to work steadily until the fall of 1945. During this time pneumothorax refills were given at intervals of ten days to two weeks. Sputum remained consistently negative and there were no clinical or roentgenologic evidences of activity. During the summer of 1945 decision was made to abandon pneumothorax and refills were stopped. The collapsed lung proved to be nonexpandable and pleural effusion developed with symptoms of pain and tension which required thoracenteses repeated at intervals of seven to ten days for relief. She had been having these thoracenteses up to the time of admission to the hospital in January, 1946.

Treatment.—Thoracentesis was productive of 750 c.c. of thin, amber, slightly cloudy nonodorous fluid from which was cultured *Staphylococcus albus*. It was negative for tubercle organisms on smear and culture. Repeated thoracenteses were done at two-day intervals, removing from 250 to 500 c.c. of fluid of the same character, and replacing in the pleural cavity at the completion of each tap 100,000 units of penicillin. After the fourth thoracentesis the vital signs returned to normal and symptoms subsided. Smears and cultures from subsequent taps were all negative for pyogens and tubercle bacilli. Despite the fact that pleural fluid reaccumulated, symptoms were minimal, and no further thoracenteses were done. The patient was discharged from the hospital, and remained under observation at home. She re-entered the hospital in June, 1946, for attempted decortication and reexpansion and operation was done on June 6, 1946.

Operative Note.—Left posterolateral thoracotomy incision with resection of the fifth rib was done. Fibrosed parietal pleura about ¼ inch thick was incised and the hydropneumothorax space entered. This space extended from the apex to the diaphragm and occupied about 50 to 60 per cent of the left pleural cavity. About 300 c.c. of slightly cloudy serous fluid were removed by suction, and several handfuls of gelatinous fibrin were removed from the bottom of the cavity and wiped from its lining walls. The cavity was lined by a firm, tough, well-organized fibrous plaque about ¼ inch in thickness with a smooth yellowish-white surface. The mid-portion of this plaque covering the collapsed lung was carefully incised until the visceral pleura was reached. The edges of the incised plaque were grasped with Allis forceps and elevated and it was found that a distinct line of cleavage could be developed between the inner surface of the plaque and the intact visceral pleura. By careful and painstaking blunt dissection with gauze tips, following this line of cleavage, it was possible to dissect this plaque off the entire surface of the collapsed upper and lower lobes. It was necessary to make a second intercostal thoracotomy incision in the eighth interspace to complete the dissection of the fibrous plaque from the lower portion of the lower lobe and the diaphragm. The plaque was then resected around its periphery at its angle of reflection onto the parietal pleura of the chest wall. The portion of the plaque on the parietal pleura was left in place. The lung lobes were then entirely freed up by separating the loose fine areolar adhesions between them and the remaining portions of the chest wall, mediastinum, and diaphragm, and the interlobar fissure was likewise separated. The lung was then expanded by intratracheal positive pressure. The lower lobe and the lower two-thirds of the upper lobe expanded fully and well. The upper one-third of the upper lobe, which was the seat of the original tuberculous lesion, was firm and fibrotic, and did not aerate. No. 45

CASE 2.—K. D., a 29-year-old white woman, was readmitted to Triboro Hospital in September, 1945, for treatment of a tuberculous cavity in right upper lobe, and recurrence of positive sputum.

Past History.—Original admission to Triboro Hospital in June, 1944, with history of onset with cough, sputum, and fever was in April, 1944. At that time the patient was in the third month of pregnancy. Sputum was positive for tuberculosis. X-ray examination showed a large thin-walled cavity in the left apex. Left pneumothorax was initiated in July, 1944, and closed intrapleural pneumonolysis was performed in September, 1944. During December, 1944, she was delivered of a full-term normal baby. February, 1945, a repeat pnuemonolysis resulted in complete collapse of the left upper lobe, cavity closure, and sputum conversion. She was discharged from the hospital in April, 1945, and continued pneumothorax treatments in the outpatient department. In July, 1945, sputum again turned positive and x-ray examination revealed a new thin-walled cavity in the right upper lobe. She was readmitted to Triboro Hospital in September, 1945.

Status on Admission.—General condition of the patient was good. Sputum concentrates were positive for tuberculosis. Sedimentation rate was 38 mm., vital capacity 1,600 c.c. Tomographic x-ray views of both lungs showed a 3 by 2 cm. cavity in the right apex, and no residual cavity in the collapsed left upper lobe.

Attempted therapeutic pneumothorax on the right was unsuccessful. Due to low vital capacity it was considered essential to obtain some re-expansion on the left before right upper thoracoplasty could be undertaken. Left pneumothorax was abandoned but after several months the left lung failed to re-expand appreciably. X-ray appearance suggested that a thick fibrous plaque covered the collapsed and enfolded lung. This was confirmed by thoracoscopy. Bronchoscopy in February, 1946, showed no intrabronchial pathology. In the meantime on strict bed rest general condition of the patient and x-ray appearance of the right lung cavity remained unchanged. Vital capacity had dropped to 1,500 c.c. Decision was made to attempt decortication and re-expansion of the left lung prior to right thoracoplasty. On April 16, 1946, under intratracheal ether-O_2 anesthesia a left thoracotomy and decortication of the left lung were performed.

Operative Note.—Left posterolateral thoracotomy incision was done with resection of the fifth rib and entrance to the pleural cavity through its periosteal bed. The lung was found about 60 per cent collapsed and broadly adherent to the cupola as well as to the posterior and anterior chest walls. The entire lung was encased in a thick grayish-white layer of hyalinized fibrous tissue which could be separated from the visceral pleura by sharp and blunt dissection, leaving an intact and normal-appearing visceral pleura. Over a small area across the upper lobe this peel was firmly adherent and on separation of its lower edge the pleura was torn and a small caseous area denuded. The freed edge of the peel was cut around this adherent arc leaving a round plaque about the size of a quarter attached to the lung. The lower edge of this plaque was sutured to the surrounding lung tissue to cover the denuded caseous area. Very little oozing was encountered, and the lung inflated readily except for the upper portion of the upper lobe which showed some puckering, and failure of expansion with positive intratracheal pressure in an area corresponding to the previously diseased, and at present fibrotic, parenchymal portion. The freely expanding part of the lower lobe and the lingula seemed to fill the chest completely. The pleura was then closed with interrupted sutures, after two L-shaped drainage tubes were placed into the pleural cavity, one in the second anterior interspace, and connected with water-seal bottles. The wound was closed in layers; 500 c.c. of whole blood were given during operation. The patient left the operating room in satisfactory condition.

Postoperative Course.—Postoperative x-ray views showed immediate and almost complete re-expansion of the left lung. The previous cavity area in the upper lobe did not re-expand, and in the ensuing months showed no sign of reopening or reactivation. The pleural space was obliterated except for a very small supra-apical fluid collection, which eventually partially absorbed and partially organized. The expansion tubes were removed at

French latex right-angle drainage tubes were placed into the pleural cavity through stab wounds in the third anterior and seventh posterior interspaces. These were later connected with water-seal drainage bottles. The two thoracotomy wounds were closed using interrupted, layer sutures of chromic catgut, with continous fine silk for the skin closure. The lung was kept expanded by intratracheal, positive pressure until closure was completed. Continuous blood transfusion had been given during operation. Blood loss was minimal, and patient's condition at the close of operation was excellent.

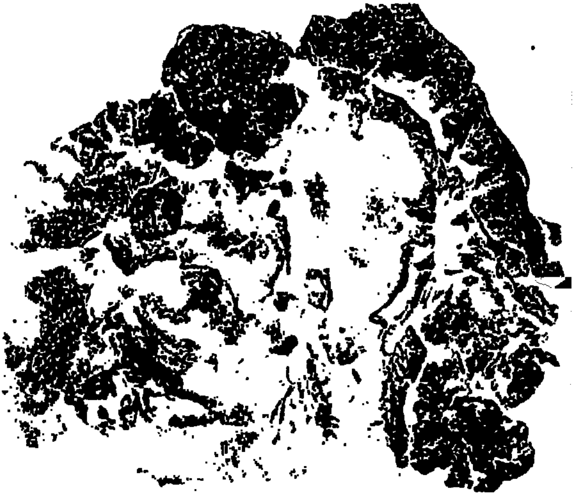

Fig. 5 (Case 1).—Juxtapleural surface of peel removed at operation.

Postoperative Course.—Postoperative convalescence was most satisfactory. She was out of the oxygen tent on the third postoperative day and out of bed on the fifth postoperative day. Water-seal expansion tubes were removed on the fourth postoperative day. She continued to have a slight elevation of temperature to 100° F. until the thirteenth postoperative day, after which the vital signs remained normal. She was discharged on the sixteenth postoperative day ambulatory and in good condition. Discharge x-ray views showed an 85 to 90 per cent re-expansion of the left lung with a small residual area of hydropneumothorax, leaving eventually a small dense shadow at the left apex.

In October, 1946, she resumed part-time work as a nurse for a trial period of one month, following which she resumed full-time work which she has continued up to the present. At no time has there been any clinical or roentgenologic evidence of re-opening of the left apical cavity or reactivation of the tuberculosis. There has been no cough or sputum, and gastric washings have been consistently negative up to October, 1947.

Comment.—The indication for decortication in this case was obliteration of the pleural dead space resulting from a postpneumothorax nonexpandable lung and its accompanying recurrent effusions, once infected with pyogens, and the avoidance of multiple stage deforming thoracoplasty to accomplish this. The result to date has been most satisfactory.

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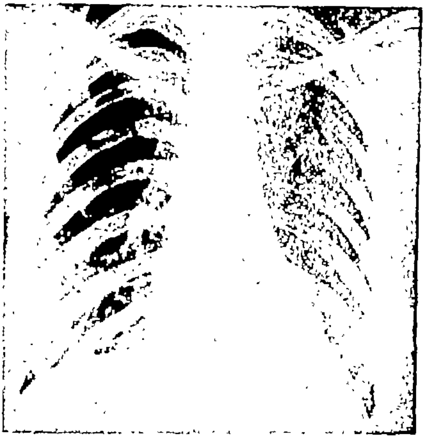

Fig. 6 (Case 2).—Jan. 4, 1946, left pneumothorax with nonexpandable lung. Right upper lobe cavity. Prior to left decortication.

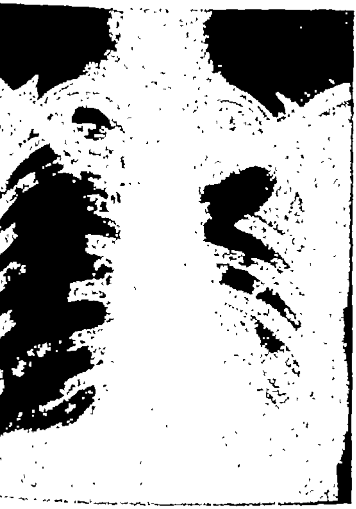

Fig. 7.

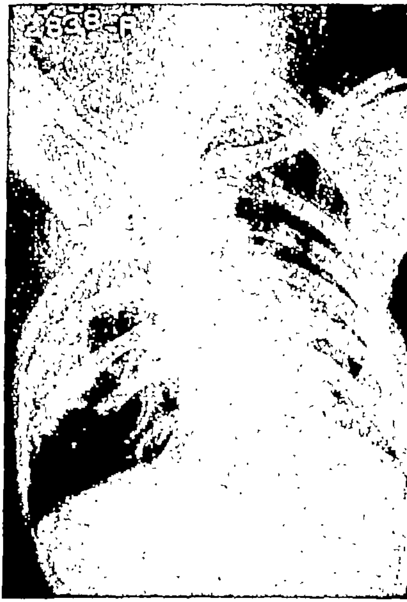

Fig. 8.

Fig. 7 (Case 2).—May 22, 1946, postdecortication. Complete expansion of left lung and obliteration of pneumothorax space. Note poor aeration of fibrosed left apical area, and increased size of right upper lobe cavity.

Fig. 8 (Case 2).—Sept. 3, 1947, seventeen months after left decortication. Fourteen months after right thoracoplasty.

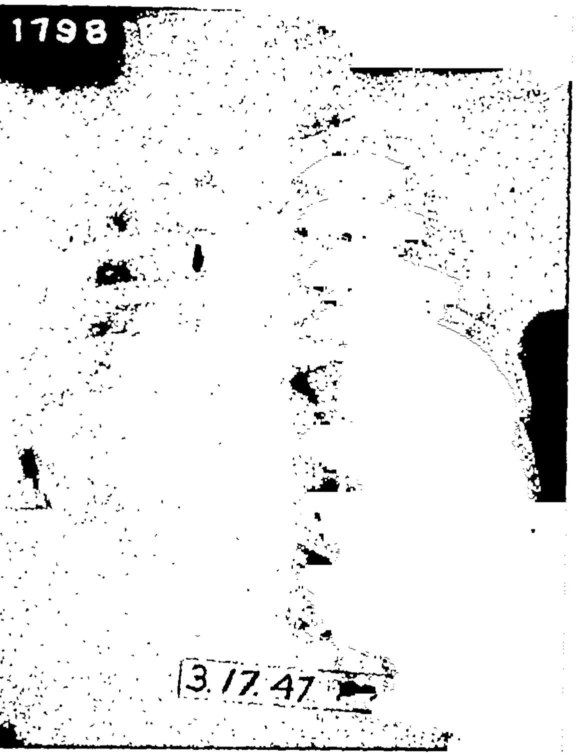

Fig. 12.

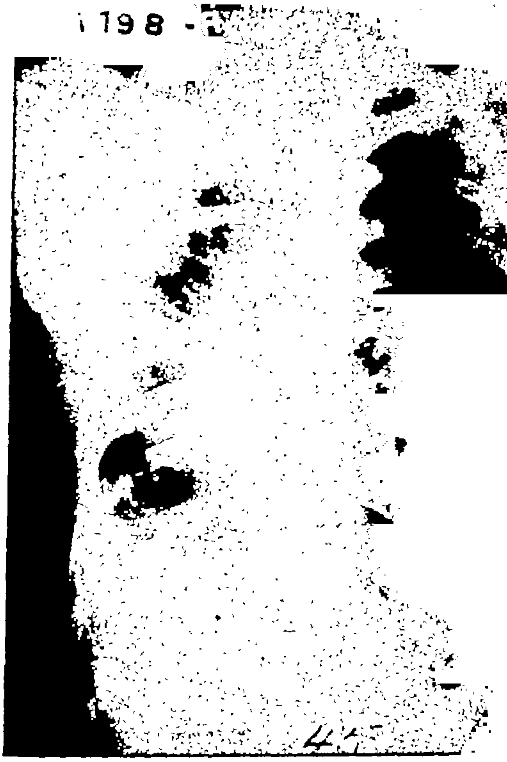

Fig. 13.

Fig. 12 (Case 3).—March 17, 1947, predecortication. Hydropneumothorax, right. Nonexpandable lung after fourteen years of artificial pneumothorax.

Fig. 13 (Case 3).—Aug. 12, 1947, five months after decortication. Complete obliteration of the right pleural space.

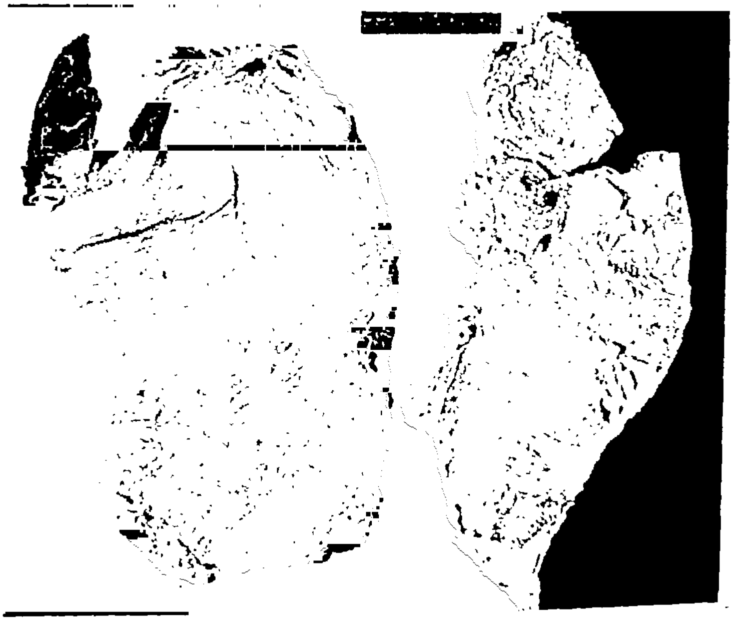

Fig. 14 (Case 3).—Fibrous plaque removed by decortication. Left is plaque removed from parietal pleura. Right is plaque removed from visceral pleura.

forty-eight and seventy-two hours, respectively, after operation. The clinical course was benign and there was no adverse effect on the contralateral lesion. About one month after *decortication the vital capacity had increased slightly to 1,600 c.c., and by July, 1940, it had* increased to 1,900 c.c.

On July 16, 1946, an upper stage right thoracoplasty with removal of the upper three ribs was performed. This was followed on July 31 by a second stage in which the fourth, fifth, and sixth ribs and the lower one-third of the scapula were removed. Sputum decreased but remained positive and a small residual cavity was visualized. On Dec. 3, 1946, a revision of the thoracoplasty was done. Following this operation cough and sputum practically disappeared, but three-day concentrates and gastric washings continued to show tubercle bacilli, and tomograph studies demonstrated a small residual cavity in the costovertebral gutter. General condition was excellent, and there was no dyspnea. The patient had gained twelve pounds since the original operation.

On May 2, 1947, *a second revision with intrapleural apicolysis and supra-apical muscle* transplant finally achieved cavity closure and sputum conversion.

Comment.—The object of decortication and re-expansion in this case was to achieve sufficient increase in functional capacity to permit a permanent collapsing operation urgently indicated for cavity closure on the contralateral side. That the procedure was eminently successful has been attested by the subsequent course of events.

CASE 3.—O. S., a white man aged 33 years, was admitted to Triboro Hospital Feb. 17, 1947, with right pneumothorax of fourteen years' duration and nonexpandable lung.

Past History.—From previous history it is noteworthy that the disease started in 1933 when the patient developed a cavitary tuberculosis of the right upper lobe for which he was hospitalized and artificial pneumothorax instituted. A pneumonolysis was performed in 1939 and the positive sputum converted. In 1935 he was discharged from the hospital with the pneumothorax maintained. He was well until 1939 when he developed a disseminated lesion in the left upper lobe, for which he was treated on conservative therapy at Bellevue Hospital and at Sea View Hospitals. According to the patient's statement, a cavity on the left side developed and disappeared. In 1942, the cavity on the left side reopened and the sputum turned positive. Re-expansion of the right pneumothorax was attempted unsuccessfully, *resulting in a temporary hydropneumothorax.* For this last episode the patient was hospitalized at Triboro Hospital from November, 1942, to April 1943, when he was discharged with negative sputum. The patient was well for three years. The pneumothorax was *maintained during this time with monthly refills to avoid symptoms of tension and* recurrence of hydrothorax.

He was admitted to Triboro Hospital March, 1946, and right phrenemphraxis was done to help obliterate right pneumothorax space. He was discharged in June, 1946.

Status on Admission.—Sputum at the time of admission was still negative and all laboratory findings were normal. Vital capacity was 3,000 c.c. Bronchoscopy March 1, 1947, showed a collapsed slitlike right main bronchus but no stenosis. Reviewing the old x-ray pictures it was noticed that there was some re-expansion of the lung between May, 1945, and March 17, 1947. The x-ray view taken on May 18, 1947, showed an almost completely collapsed lung dotted with calcified foci. This view showed also an anterior herniation of the left lung into the right pneumothorax space. The x-ray picture of March 17, 1947, showed the right lung about 70 per cent expanded. The right lower lung field showed linear fibrosis and there was a calcification over the entire lung. The apex of the right lung showed emphysematous blebs and superimposed over the right lung field just beneath the clavicle one noted a semicircular line suggesting the herniation of the left lung through the anterior mediastinum into the right pneumothorax space. At the base of the pneumothorax space there was a low fluid level noted.

of the space. The anterior upper portion was occupied by a herniated portion of the left lung, posterior to which there was an apical cap of thickened parietal pleural and organized fibrin. The costophrenic angle was obliterated, and the shift of the heart and mediastinum to the right was about the same as it was preoperatively.

Comment.—The objective of obliteration of the right pleural space after artificial pneumothorax of fourteen years was achieved. The result was highly satisfactory from the patient's standpoint, as he was completely relieved of symptoms of tension and dyspnea, and stated that breathing was easier. He was in addition relieved of the necessity of periodic refills and thoracenteses for recurrent fluid. He has been discharged from the hospital for the past four months and is able to work at his profession as a commercial artist.

CASE 4.—V. J., a 34-year-old white woman, was admitted to Triboro Hospital Dec. 16, 1946, from the outpatient department with the complaint of occasional intractable coughing spells.

Past History.—Onset of tuberculosis was in the spring, 1939. Artificial pneumothorax was induced in April, 1939, for cavitary lesion of the left upper lobe. Pneumonolysis was done in November, 1939. Adequate collapse and sputum conversion were achieved in December, 1939. During the intervening years until this admission she was in and out of sanatoriums and hospitals, and was followed a greater part of the time in the outpatient department of Triboro Hospital. Pneumothorax was maintained and sputum was always negative. During the year previous to admission attempts to abandon pneumothorax and re-expand the lung were unsuccessful due to symptoms of tension, pulling, intractable cough, and development of small intrapleural effusion.

Present Admission.—Pulse and temperature were normal. Blood count and urinalysis were also normal. Sedimentation rate was 3 mm. per 1 hr. Sputum and gastric washings were negative for tubercle bacilli on smear and culture. X-ray examination showed an 80 per cent left pneumothorax with a small pleural effusion. Tomographic plates of both lungs revealed no cavitary pathology. Bronchoscopy revealed no intrabronchial cicatricial stenosis, but the left main bronchus was collapsed to a slitlike opening. Thoracoscopy done in February, 1947, showed the pneumothorax space to be lined with hyalinized fibrous tissue which obliterated all fissures and other anatomic landmarks. Vital capacity was 1,700 c.c. The patient insisted firmly on abandoning pneumothorax refills after 7½ years. Decortication was suggested and accepted by the patient with thoracoplasty to follow if re-expansion was unsuccessful. Decortication was performed on Feb. 26, 1947.

Operative Note.—Operation was performed with intratracheal general oxygen ether anesthesia. A left postero-lateral thoracotomy incision was made. The sixth rib was resected from the transverse process to the anterior axillary line. Incision was made into the pneumothorax space through the periosteal bed of the resected rib. The parietal pleura was thickened to about ¼ inch, and cut with a hard, gritty feel. When the pneumothorax space was entered it was found to be completely dry and lined with a pearly white, thick fibrous plaque. The lung was wholly collapsed against the mediastinum and posterior costovertebral gutter, and held down by this thick fibrous plaque. There was no expansion of the lung whatever, even under positive intratracheal pressure. The mid-portion of the plaque over the lung was carefully incised until the visceral pleura was reached. Between the inside of the fibrous plaque and the visceral pleura a line of cleavage was developed in which, by careful blunt dissection with gauze and with a gloved finger, the plaque could be separated from the visceral pleura. The plaque was divided thus, away from the lung and mediastinum anteriorly as far as its reflection on the anterior chest wall and posteriorly as far as its reflection on the posterior chest wall and upward along these lines to the extreme apex. The plaque was then cut along its angle of reflection to the chest wall and removed. Corresponding dissection was carried out on the lower half of the

Operative Note.—The decortication was performed March 21, 1947, under intratracheal general oxygen-ether anesthesia. The operative procedure in this case was rather an extensive one.

A right posterolateral thoracotomy incision was made with resection of the sixth rib. The pleural cavity was entered through the periosteal bed of the sixth rib. The parietal pleura was about ¼ inch thick and composed of hyalinized fibrin. In the pleural cavity there were about 300 to 400 c.c. of clear, thin fluid slightly tinged with methylene blue, which had been injected previously. The hyalinized fibrin plaque covered the entire pleural space. The lung was moderately expandable under positive pressure. After removal of the fluid the fibrin plaque over the lower lobe was incised down to the visceral pleura and a plane of cleavage developed between the inside of the plaque and the surface of the lung. No real loose plane of cleavage could be found and dissection was tedious and difficult. The thick hyalinized plaque was stripped off the chest wall and the upper half dissected around the apex with extreme difficulty. In dissecting the plaque away from the upper mediastinum most of the mediastinal pleura came with it, exposing the venacava and the phrenic nerve. After this portion of the plaque had been freed from the chest wall and mediastinum it was dissected off the remainder of the upper lobe. A small portion of the posterior apical area was composed of a large emphysematous bleb and this came away attached to the plaque. The raw surface of the lung thus exposed did not bleed and it was repleuralized by inverting the edges of the visceral pleura with a fine catgut suture. A similar dissection was then carried out to strip the plaque from the lower half of the chest wall and the lower and middle lobes. Here again the dissection was extremely difficult, especially along the mediastinal surface and over the diaphragm, and finally, a patch of the plaque about 3 inches in diameter was left attached to the diaphragm. It was necessary also to leave a similar patch about 2 inches in diameter on the lateral surface of the lower lobe. The lung was then re-examined by positive intratracheal pressure. The remaining portion of the upper lobe aerated and expanded very poorly; the lower lobe expanded fairly well and filled about one-half of the chest cavity. The pleural cavity and lung were then sprinkled with streptomycin-plasma mixture and 100,000 units of penicillin were placed into the pleural cavity. Two No. 45 right angle latex drainage tubes were introduced into the pleural cavity in the third anterior interspace, and in the ninth lateral interspace, to be later connected with water-seal bottles. The thoracotomy wound was then closed in layers with interrupted catgut sutures.

Note.—The procedure was extremely rough and shocking but the continuous blood transfusion throughout the operation maintained the patient's pressure at a level about 100 and at the close of the operation the pressure was 110/70. He returned to the ward in good condition.

Postoperative Course.—Postoperatively the patient received daily 1 Gm. streptomycin and 150,000 units penicillin parenterally, and 50,000 units penicillin and 400 mg. streptomycin locally into the pleural space for one week. The lung did not show immediate complete re-expansion. There was residual pneumothorax at the apex of the right pleural cavity, and also evidence of air leakage from the lung noticed in the water-seal system for the first four postoperative days, undoubtedly due to the injuring and suturing of emphysematous lung tissue during the operative procedure. Fluid drainage was minimal. The lower drainage tube was removed on the fourth postoperative day. The upper tube was removed on the eighth postoperative day, forty-eight hours after evidence of gross air leakage ceased. The apical residual pneumothorax was deflated at twenty-four to forty-eight hour intervals by removal of 30 to 50 c.c. of air to maintain satisfactory negative pressures. On one of these thoracenteses the herniated left lung was punctured by the needle and the left traumatic pneumothorax resulted. This tension pneumothorax was treated by continuous deflation for forty-eight hours. The left lung re-expanded and the episode passed without any sequelae. The right pleural space subsequently became entirely obliterated (see postoperative x-ray picture, Fig. 13, Aug. 12, 1947). The re-expanded right lung filled about four-fifths

Comment.—This case represents a classical indication for decortication of a nonexpandable lung. The tuberculous process seemed to have been arrested for over seven years. No bronchial pathology or extensive parenchymal fibrosis could be held responsible for the nonexpansion. The cause of the nonexpandability seemed to be chiefly the constricting fibrous coating of the pleura due to the chronic pneumothorax. The annoying symptoms and the intense desire of the patient to abandon pneumothorax refills dictated some surgical procedure for the obliteration of the pleural space. The successful surgical re-expansion spared the patient an extensive multiple stage thoracoplasty with its resultant deformity. No adverse effect has occurred up to eight months postoperatively on the course of the arrested tuberculosis.

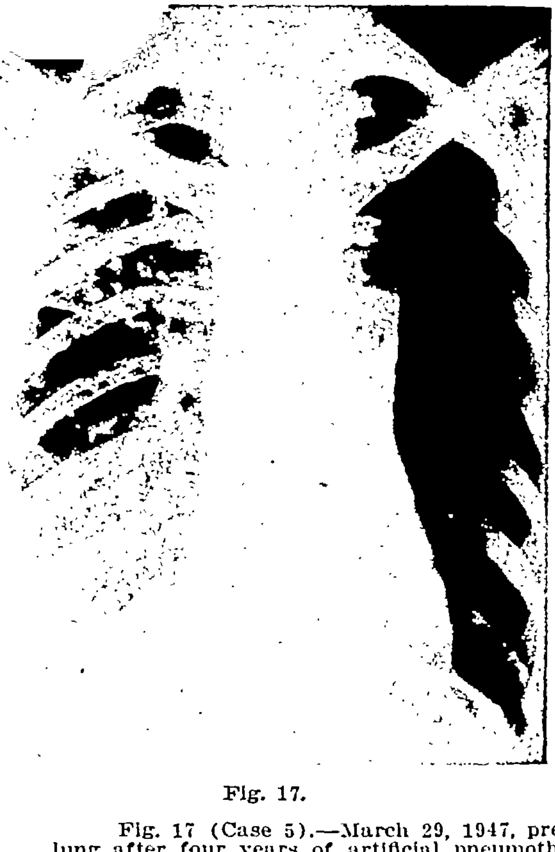

Fig. 17.

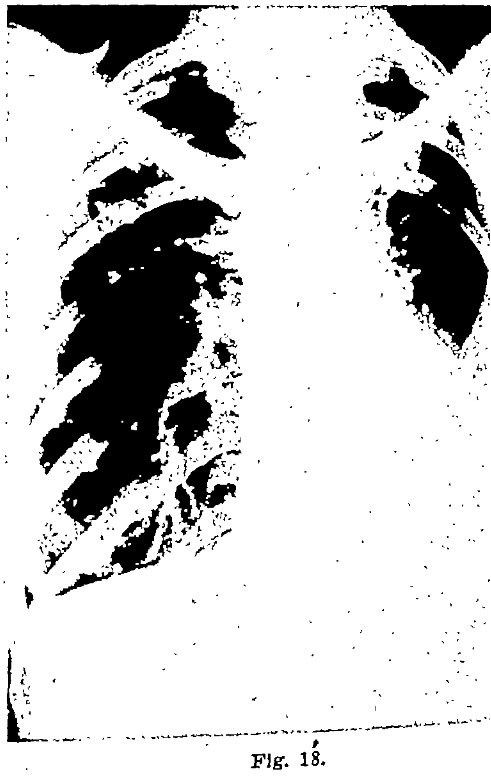

Fig. 18.

Fig. 17 (Case 5).—March 29, 1947, predecortication. Completely collapsed nonexpandable lung after four years of artificial pneumothorax.

Fig. 18 (Case 5).—Aug. 27, 1947, 2½ months after technically complete decortication. Residual pneumothorax space and failure of re-expansion of left lung due to parenchymal fibrosis.

CASE 5.—M. K., a white 33-year-old woman, was re-admitted to Triboro Hospital, March, 1946, because of fresh spread of tuberculous lesion in right upper lobe.

Past History.—Original admission to Triboro Hospital was in June, 1942, with a history of onset of symptoms and diagnosis of pulmonary tuberculosis in September, 1941. The patient had had no treatment prior to this admission. X-ray pictures showed diffuse nodular infiltration of the right apex and left upper lobe; a like type of lesion plus small cavities in the left lower lobe. Sputum was positive for tuberculosis. Treatment of bed rest until March, 1943, when a left pneumothorax was induced. In early 1944 a fresh exudative lesion occurred in the right upper lobe. Bronchoscopy at this time was negative. The patient's lesion on the right showed resolution on strict bed rest. She was discharged to the plaque dissecting it free from the lower lobe and the diaphragm, and then removing it. Attempt was then made to re-expand the lung by positive intratracheal pressure, but it did not re-expand very well. There was a rather marked intrapleural fibrosis across the medial aspect of the midlung field having a stellate character and broadening out into a fibrotic band about 1 inch in width which ran posteriorly. This seemed to keep the lung from expanding in this area, and it was impossible to free it without opening into the lung tissue. Several small bands of adhesions on the lower lobe and at its medial surface were dissected free and this portion of the lung re-expanded fairly well. Also the anterior and upper parts of the upper lobe expanded fairly well. At one point, the dissection of the fibrous plaque from the lung loosened a small calcified tuberculous nodule about 2 mm. in diameter. This was removed. There was no purulent or caseous reaction around it. The re-expansion of the lung was disappointing. I would estimate that about only a 50 per cent re-expansion of the lung was achieved. No attempt was made to remove the fibrous lining from the parietal pleura. Two No. 45 French right angle perforated drainage tubes were placed into the pleural cavity through stab wounds in the third anterior and eighth posterior interspaces, to be later connected with water-seal bottles. The thoracotomy wound was closed in layers using interrupted No. 1 chromic catgut sutures throughout. During operation 1,000 c.c. of whole blood, and 500 c.c. of 5 per cent glucose in saline were administered. The patient left the operating room in good condition.

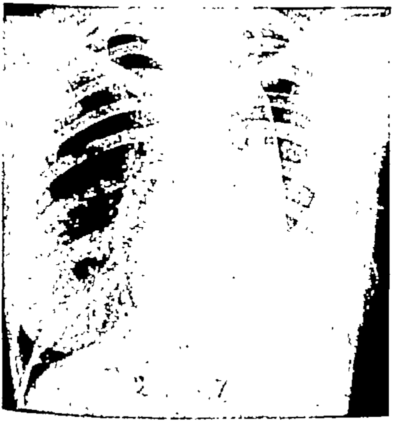
Fig. 15.

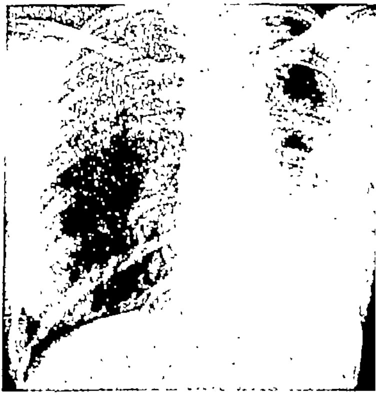
Fig. 16.

Fig. 15 (Case 4).—Feb. 18, 1947, nonexpandable lung after seven years of artificial pneumothorax.

Fig. 16 (Case 4).—April 7, 1947, six weeks after decortication. Complete re-expansion of left lung with obliteration of pleural space.

The postoperative course was uneventful. The lung re-expanded readily and filled the hemithorax. This was surprising and gratifying in view of the less optimistic expectancy during operation. The drainage tubes were removed forty-eight and seventy-two hours, respectively, after operation. The vital capacity did not increase in the first four postoperative weeks over the original 1,700 c.c. but the patient stated that breathing was much easier and felt more efficient. She was discharged May 2, 1947, from the hospital. She gained seven pounds after operation over her original weight on admission. Up to October, 1947, there has been no evidence of reactivation or reopening of old cavities.

procedure. In Cases 3 and 4, the objective was the abandonment of pneumothorax refills and the obliteration of the pleural space without resort to multiple stage thoracoplasty. In Case 1 the indication was obliteration of a postpneumothorax space subject to recurrent pleural effusions, which had once been infected with pyogens and sterilized by penicillin therapy. In Case 2 the objective was an increase in the functional capacity to permit urgently indicated thoracoplasty for contralateral cavity. The clinical results in these four successful cases have surpassed expectations. These four cases have had periods of postoperative observation of sixteen months, eighteen months, eight months, and seven months, respectively. One patient (Case 2) has subsequently undergone four stages of thoracoplasty, revision, and apicolysis to achieve cavity closure and sputum conversion for contralateral cavity. There have been no serious postoperative complications. There has been no tuberculous empyema or wound infection. There has been no clinical or roentgen evidence of reopening of cavities or reactivation of tuberculosis in the re-expanded lungs. Three patients have been out of the hospital for several months, enjoying an "apparently arrested" status, leading normal lives, and working. The fourth patient (Case 2) is ready for discharge from the hospital in an apparently arrested status.

CONCLUSIONS

Pulmonary decortication appears to be a useful procedure to add to the surgical armamentarium for dealing with the problem of the postpneumothorax nonexpandable lung.

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outpatient department in 1945 after three years of sanatorium treatment. Sputum was negative on concentrate, but persistently positive on culture. Left pneumothorax was maintained.

Present Status.—There was a fresh right upper lobe lesion with cavitation. Sputum was positive.

Treatment.—In April, 1946, marginal pneumothorax was instituted on the right. This had to be abandoned in September, 1946, because of tension pneumothorax. Refills on the left side were abandoned, but the lung failed to re-expand up to May, 1947. Vital capacity was 900 c.c. Bronchoscopy was negative. The patient was considered for a left decortication because of the low vital capacity, and desirability of permanent collapsing operation for right upper disease. It was felt preoperatively that the chances of good re-expansion with decortication were poor because of the diffuse character of the original lesion in the left lung and x-ray evidence of marked parenchymal fibrosis. Fig. 17 shows an x-ray view of the preoperative condition.

Operative Note.—Operation was done on June 9, 1947. The lung was found completely covered and bound down by a thin hyalinized fibrous plaque which was completely separated from the underlying visceral pleura with ease. The lung was completely decorticated, and freed from all adhesions to the diaphragm, pericardium, and mediastinum. The visceral pleura was thin, and in the process of decortication a few tuberculous foci immediately beneath the visceral pleura were denuded, but no caseous material escaped. It was immediately noted on completion of the freeing of the lung that there was marked parenchymal fibrosis. Intratracheal positive pressure failed to re-expand the lung or to aerate it to any satisfactory degree. After dusting the pleural surfaces with streptomycin-plasma mixture, and placing two intercostal expansion tubes, the thoracotomy wound was closed in the usual manner. Streptomycin was administered for seven days preoperatively in dosages of 1 Gm. per day, and continued for four weeks postoperatively at the same dosage level.

The postoperative course was completely benign and uneventful. The lung, however, showed only slight re-expansion, and the pneumothorax space was about as large as preoperatively (Fig. 18). There was no empyema or recurrent fluid formation and the operative wound and drainage tracts healed per primam.

Comment.—This case represents a failure to achieve lung re-expansion or obliteration of the pneumothorax space following complete decortication. The failure was due, we believe, to marked parenchymal fibrosis of the collapsed lung.

SUMMARY

Attention is called to the possibility of a new surgical approach to the problem of the postpneumothorax nonexpandable lung by means of decortication. The literature on older and more recent uses of pulmonary decortication for other indications is discussed. The pathologic factors responsible for some cases of nonexpandability, which provide the theoretical background for the use of the procedure in tuberculosis, are analyzed. Tentative indications for use of the procedure are outlined. Preoperative and postoperative care is delineated. For detailed description of operative technique reference is made to recent articles by Sampson and Burford,[1] and by Tuttle, Langston, and Crowley.[12, 13]

Detailed case histories of five patients who have had surgical decortication for postpneumothorax nonexpandable lungs are presented. One case was a failure in that obliteration of the pleural space was not obtained, and very little re-expansion of the lung resulted in spite of a complete technically successful decortication. This failure was due to marked parenchymal fibrosis of the lung. Four cases were completely successful in accomplishing the objective of the lack of familiarity with the variations in nerve patterns in our early experience. It has been observed in a study of more than 100 cadavers that the vagus nerves in the lower mediastinum fall into three main classes.

The most common type is that in which the left nerve is found to be a single main trunk in the lowest part of the esophagus, usually between the levels of 2 and 6 cm. above the hiatus. The right nerve is also a single trunk in a slightly lower area, between 2 and 4 cm. above the hiatus. A branch occasionally connects the right and left vagus nerves between the levels of 5 and 8 cm. above the hiatus. Seventy-four per cent fall into this group.

The next most common type is that in which the left vagus nerve fibers consist of a main nerve with a smaller nerve within 1 cm. of the main nerve but entirely separate from it from the level of 7 or 8 cm. above the hiatus down to the stomach. There may be small intercommunicating branches between the two. The right nerve in these cases does not differ from the common type and in general shows more branching than the left in the level between 5 and 10 cm. above the hiatus. Occasionally, it courses down the esophagus on to the stomach and celiac plexus as several branches. These branches are usually sufficiently close together to make it easy to pick up all branches at the same time when separating the nerve from the esophagus. The right nerve is loosely attached to the esophagus and is easily left behind when the esophagus is lifted from the mediastinal bed.

The third group, consisting of wide departures from the usual pattern, makes up 4 per cent of 100 specimens examined. In two of the specimens the left vagus nerve was partially submerged in the muscle. In the third specimen, the left vagus nerve was divided into five segments of about equal size. The fourth specimen showed a branch of the right vagus nerve which was intimately attached to areolar tissue of the mediastinum and free from the esophagus. This separate filament passed through the hiatus. We have seen no instances of vagus nerves passing from the thorax into the abdomen except through the esophageal hiatus.

One should not begin the separation of the vagus nerve from the esophagus too close to the esophageal hiatus. There are two reasons for this. First, one is likely to miss the fibers which leave the esophagus 1 or 2 cm. above the hiatus. Second, the left vagus nerve is intimately adherent to the esophagus in the level between 0 and 1 cm. above the hiatus and is not readily picked up in this area.

INDICATIONS FOR OPERATION

All of the patients in this series were diagnosed as having duodenal or stomal ulcer and were referred to surgery by the medical gastroenterology service because of hemorrhage, obstruction, intractable pain, or a combination of these indications. The ages of the patients ranged from 20 to 69 years.

PREOPERATIVE MANAGEMENT

Most of the patients who come to operation are in a poor state of nutrition because of dietary restrictions over a long period of time, obstruction, hemorrhage, or a combination of these factors. Protein deficiency is corrected by a

VAGUS NERVE SECTION IN THE TREATMENT OF PEPTIC ULCER

Abdominal Versus Thoracic Approach

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and Robert B. Voelker, M.D. Van Nuys, Calif.

THE widespread interest in the operation of vagus nerve section devised by Dragstedt[1] for the treatment of peptic ulcer is as much an expression of dissatisfaction with other methods of surgical treatment as it is an enthusiasm for the new procedure. The expression of dissatisfaction with other methods is not surprising when it is considered that the best of the tried methods is one in which most of the stomach is removed to eradicate a relatively benign lesion. The enthusiasm for the new procedure, based upon the excellent immediate results, is being countered with a healthy opposition which asks that its acceptance await a period of some years in order to ascertain the permanency of relief. We are in complete accord with that admonition. It is obviously impossible to discuss permanency of results in the group of patients to be reported here, as the time since operation varies from twelve to twenty months. Sixty cases are included in this group, thirty by the abdominal and thirty by the thoracic approach. This division was arbitrarily made in order to compare the relative advantages and disadvantages of the two methods. It is not easy to evaluate the results in the disease of peptic ulcer, and the comparison of results becomes more difficult when the evaluations are made by different clinics. One may arrest hemorrhage, relieve obstruction, or relieve abdominal distress without effecting complete relief from symptoms referable to the psychic phase of this psychosomatic disease. Unfortunately, the same standards are not universally used in determining the degree of relief, and this must be considered in evaluating the results of this and other operations. Classifications of complete relief, partial relief, and failure have little meaning unless one states what is meant by these three types of results.

The operation of vagal denervation of the stomach is not a simple one. Denervation is not always attained because of the difficulty of working in the relatively unfamiliar region of the lower mediastinum and the variability of the pattern of the vagus nerves, which make it difficult to be certain that the nerves are adequately interrupted. Many of the objections which have been expressed against the operation should be charged to faulty performance rather than to failure of the procedure to achieve its aim when properly performed. It is this phase of the problem that is dealt with in this presentation.

VAGUS NERVE PATTERN

It is significant that the failures with both abdominal and thoracic approaches were limited to the early cases. This may be explained in part by a

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high protein diet and amino acid infusions and blood deficiencies are corrected by transfusions. Vitamin C, 300 to 500 mg., is administered daily for at least seven days prior to surgery. The importance of correcting these deficiencies cannot be overemphasized. We are convinced that some of our early difficulties were the result of failure to appreciate the degree of malnutrition.

The insulin hypoglycemia test was used routinely before and after operation in our first cases but is now performed only postoperatively to determine the completeness of vagus nerve section. The test amounts to hypoglycemic shock and is distressing to the patient. Most of the patients subjected to the test have shown evidence of severe hypoglycemia, manifested by weakness, fainting, perspiration, hunger, and shaking. There is also the theoretical danger of inducing severe bleeding in the preoperative ulcer patient, although we have not yet seen what could be termed dangerous bleeding. For these reasons it is questionable whether the test should be used except in those cases in which failure to accomplish denervation is suspected.

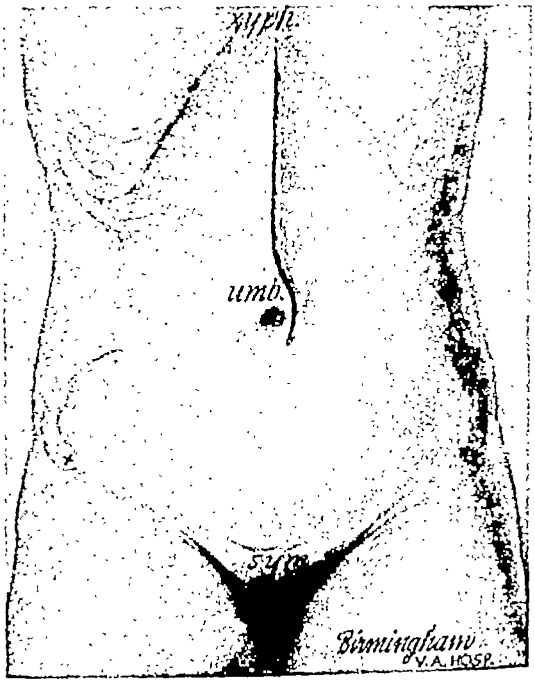

Fig. 2.—Skin incision; the abdominal incision.

The stomach and bowel are emptied preoperatively by giving a liquid diet beginning twenty-four hours before surgery, a saline cathartic in the morning, and a normal saline enema in the evening of the day before surgery. A Levine tube is introduced into the stomach prior to operation. All patients are given penicillin intramuscularly from three days before operation to five days after operation.

TECHNIQUE OF ABDOMINAL APPROACH

Spinal anesthesia is used because of its action in promoting peristalsis and in facilitating exposure.

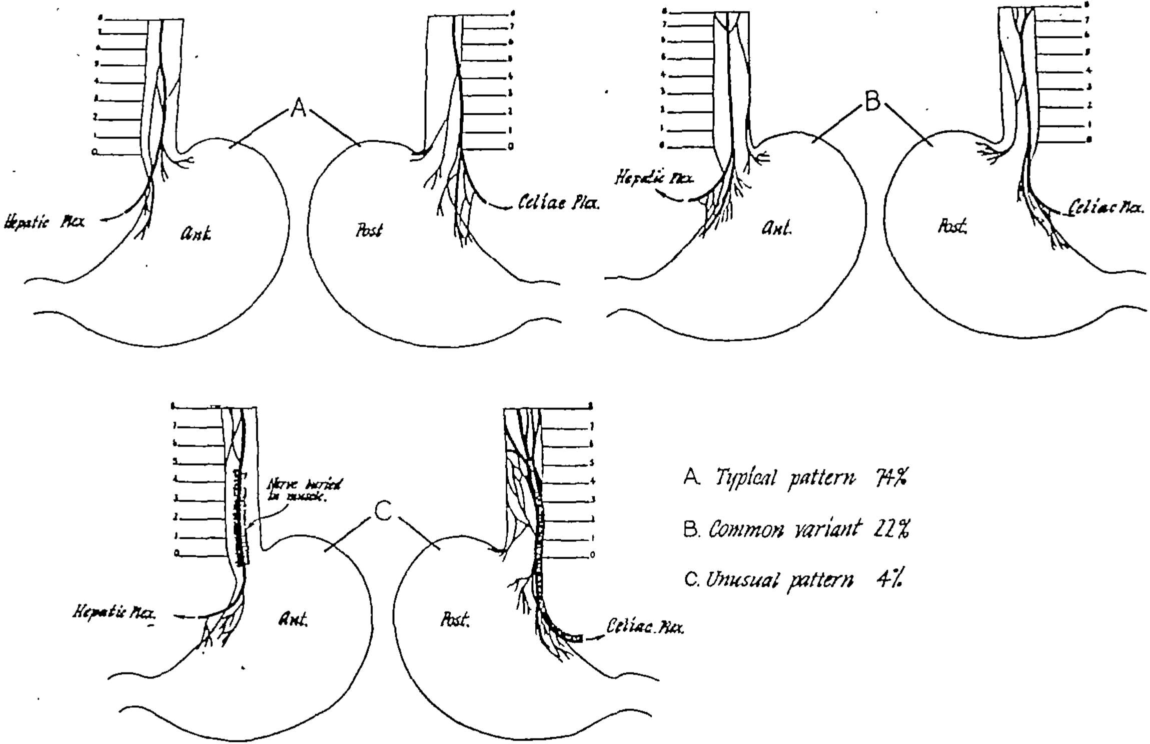

Fig. 1.—Representative vagus nerve patterns in the lower mediastinum.

stomach and intestines are retracted with the gloved hand and a transverse incision 2 to 3 cm. in length is made through the peritoneum covering the esophageal hiatus. The left subphrenic vein, which courses transversely just anterior to the hiatal ring, is carefully avoided. The right index finger

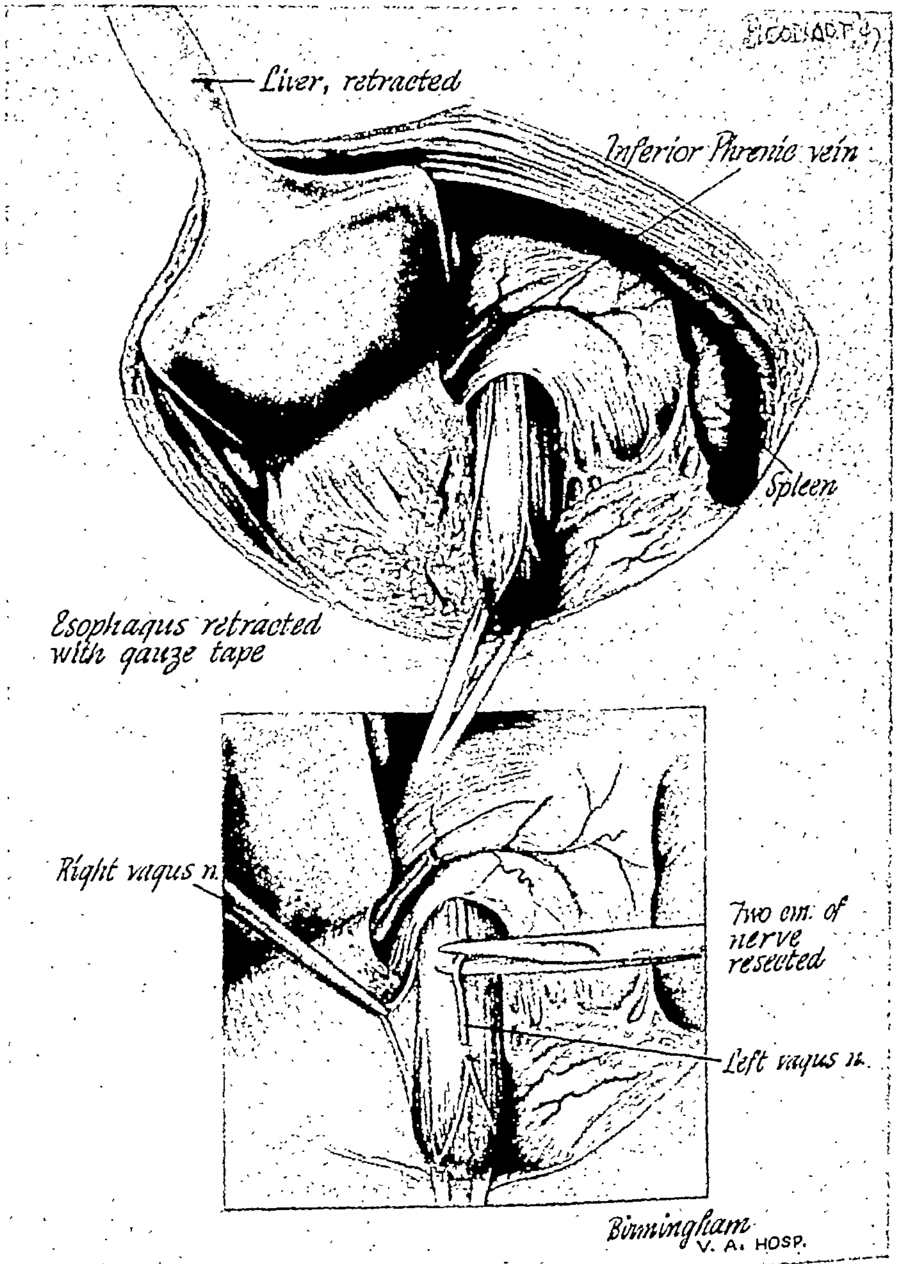

Fig. 4.—Resection of nerve segment between ligatures.

is inserted through the incision into the esophageal hiatus an [illegible] rates the esophagus and vagus nerves from the adjacent mediast [illegible] agus, with the attached nerves, is then drawn into [illegible] the flexed index finger, and an empty Penrose r [illegible]

An incision is made through the abdominal wall 2 cm. to the left of the midline, extending from the ensiform cartilage to 2 cm. below the umbilicus. The stomach, duodenum, and other upper abdominal viscera are examined, noting the degree of activity of the ulcer. It is impossible to determine the degree of pyloric obstruction by inspection or palpation and roentgenologic examination must be relied upon for this information.

The left lobe of the liver is retracted upward and to the right by means of a broad retractor designed for this purpose. Adequate exposure of the hiatus may be obtained without division of the left hepatic ligament. The

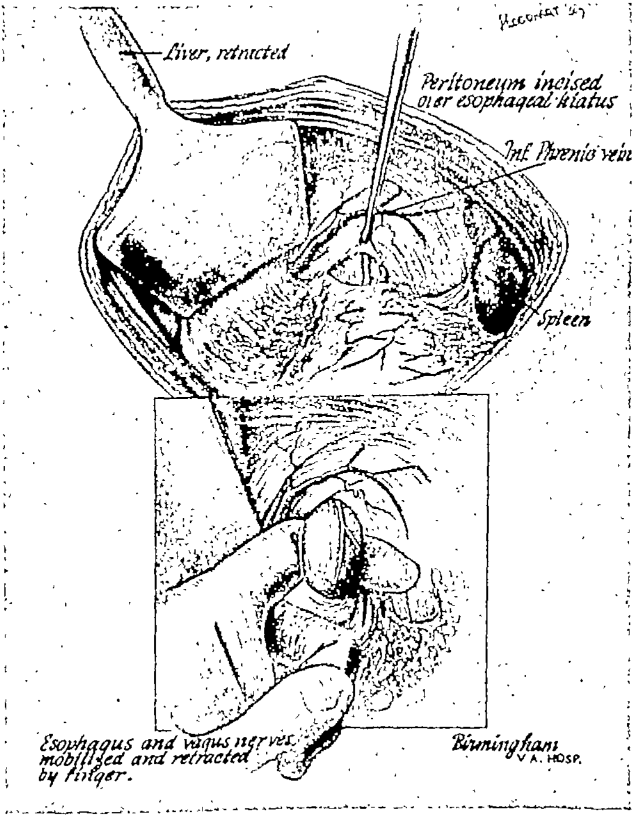
Liver, retracted
Peritoneum incised over esophageal hiatus
Inf. Phrenic vein
Spleen
Esophagus and vagus nerves mobilized and retracted by finger.
Birmingham V.A. HOSP.

Fig. 3.—Left lobe of liver retracted cephalad and to right. Peritoneum over esophageal hiatus incised, exposing esophagus. Insert shows esophagus retracted by index finger.

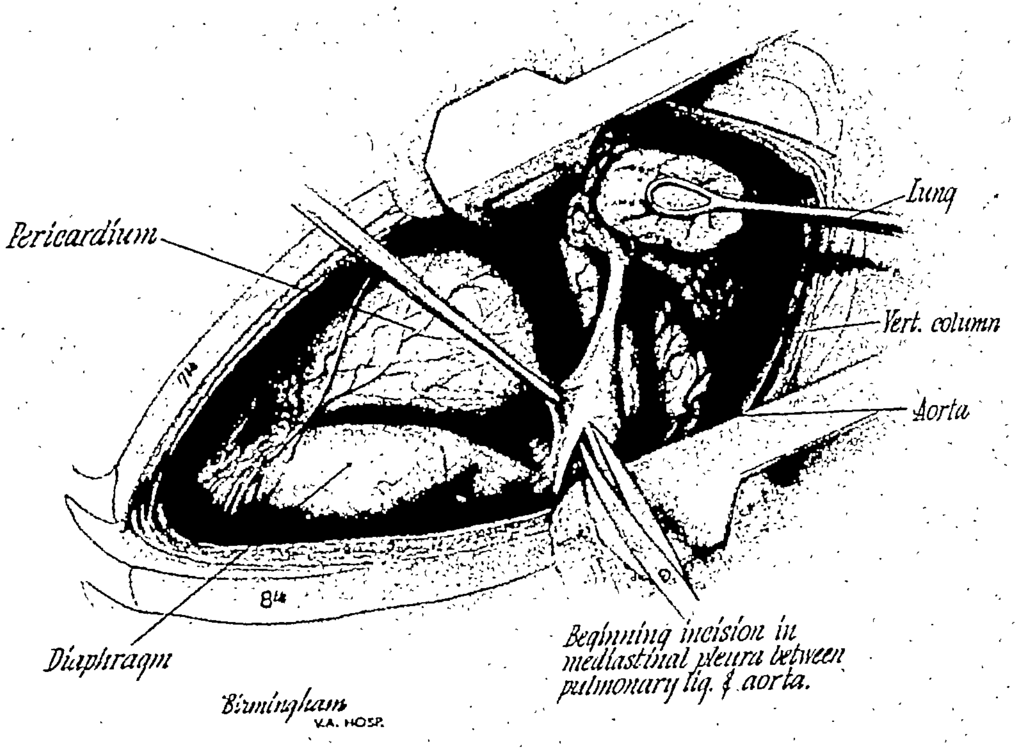
Pericardium
Lung
Vert. column
Aorta
7th
8th
Diaphragm
Beginning incision in mediastinal pleura between pulmonary lig. & aorta.
Birmingham V.A. HOSP.

Fig. 6.—Adequate exposure without sectioning rib. Retraction of lung with sponge on holding forceps. Incision in mediastinal plura to expose esophagus.

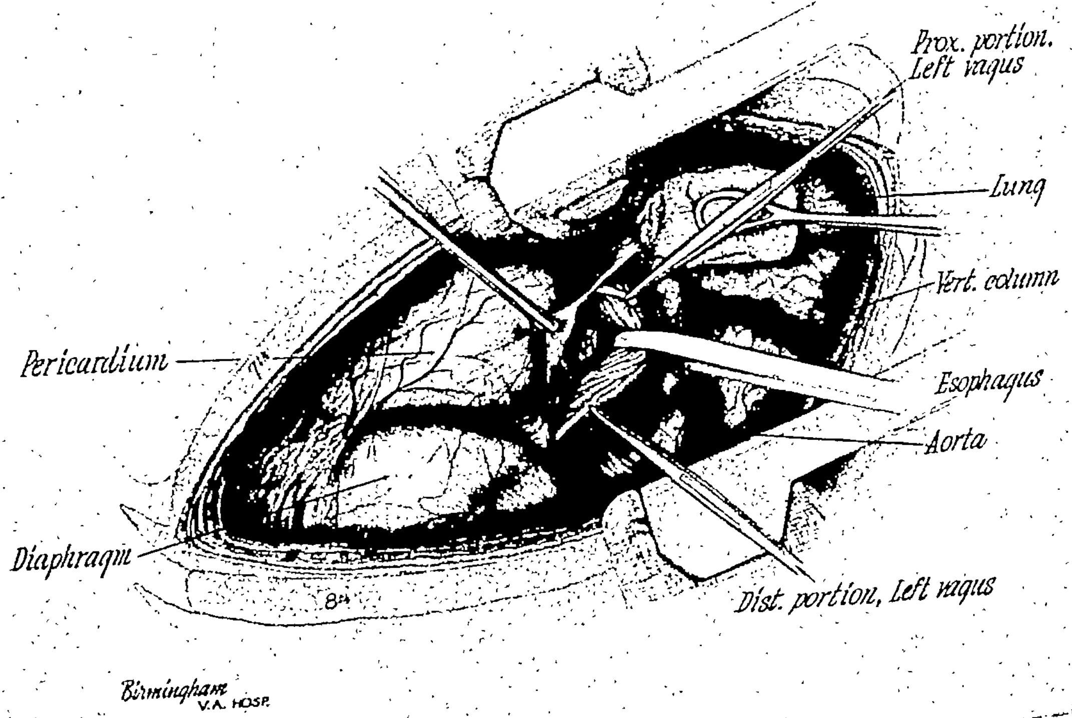

Fig. 7.—Esophagus retracted by gauze tape; segment of vagus nerve resected between ligatures.

it for traction. At least 6 cm. of the esophagus can be brought into view by this maneuver. The nerves are identified by palpation and inspection. Clamps are placed 2 cm. apart on each of isolated vagus nerves and the segment between the clamps is resected. The divided ends of the nerve are ligated with cotton suture. Small nerve filaments are transected without ligation. The resection of a segment is usually performed between 2 and 4 cm. proximal to the hiatus, since the nerves are more integrated at this level. After division of the vagus nerves has been completed, the penrose tube is withdrawn and the esophagus is returned to its bed. The peritoneal incision over the hiatus is not sutured. Gastroenterostomy is performed if there is existing or anticipated obstruction at the pyloric ring. The abdominal wound is closed in layers, using interrupted sutures for the fascial layers.

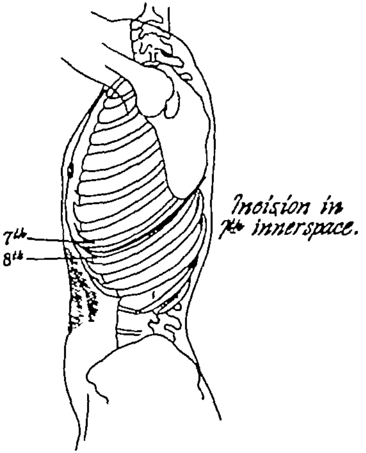

Fig. 5.—Incision in seventh interspace, left, from mid-scapular line to costochondral junction.

THORACIC APPROACH

Endotracheal anesthesia with nitrous oxide, oxygen, and ether is supplemented with curare. The lungs are inflated at intervals of 20 minutes or less while the pleural cavity is open.

An intercostal incision is made in the seventh interspace extending from the midscapular line to the costochondral junction. Sufficient exposure is obtained without coastal resection. Heavy gauze packs are placed between the blades of the rib spreader and tissues to lessen trauma. Pleural adhesions which may be present in the field of operation are divided and the lung is retracted upward with a sponge on holding forceps. Diaphragmatic excursions are inhibited with curare. A longitudinal incision 6 cm. in length is made in diet several days longer. A general diet is allowed after twelve days, but the patient is admonished not to overload the stomach at any one meal.

COMPLICATIONS

Few of the complications are common to both operations. For this reason, the complications will be discussed separately under each of the approaches.

COMPLICATIONS WITH ABDOMINAL APPROACH

All of the abdominal complications occurred among the first twelve cases and were principally due to faults which have been overcome by improved preoperative and postoperative care and improved surgical technique.

Two patients with dehiscence of the abdominal wound and three patients with postoperative hernia may be grouped together for discussion. One patient with dehiscence, a severe asthmatic patient aged 68 years, was a known poor risk, but operation was imperative because of three episodes of bleeding. A combination of excessive handling of the intestines at operation contributing to distention, and an uncontrollable cough postoperatively, could well account for the rupture of the abdominal wound. In all of the other cases, including one patient aged 69 years, excessive distention, malnutrition, and cough are blamed for the postoperative weakness of the abdominal wall. Improvement of technique by better relaxation, less handling of the intestines, more effective closure of the wound, closer attention to continuous gastric suction, and better preoperative nutrition have done away with the complication in all except the first twelve patients operated upon by the abdominal approach.

TABLE I. POSTOPERATIVE COMPLICATIONS IN THIRTY PATIENTS WITH THE ABDOMINAL APPROACH

COMPLICATION	NUMBER OF CASES
1. Dehiscence of the abdominal wound with evisceration	1
2. Partial wound dehiscence	1
3. Postoperative hernia	3
4. Intestinal obstruction	2
5. Bronchial pneumonia (one death)	2
6. Phlebothrombosis with pulmonary embolism	1

Two patients developed obstruction on the seventh and twentieth postoperative day, respectively. This is probably more than a coincidence. The intestine appears to undergo peculiar segmental contraction in the early days following vagus nerve interruption, possibly due to the sudden removal of vagal control. Attention has been directed to this phenomenon by Alvarez.[2] Unregulated bowel activity and distention are assumed to be the principal factors leading to obstruction in these cases. If this assumption is correct, closer attention to deflation by continuous gastric suction postoperatively should lessen its incidence.

Distention of the stomach and intestines and elevation of the diaphragm are considered to have been factors in the two cases of postoperative pneumonitis. The patient who died, a prematurely aged individual who was considered a relatively poor risk, was overconstricted with a tight abdominal binder, and did not tolerate well the presence of the gastric tube. Since then, the training of the mediastinal pleura between the pulmonary ligament and the aorta, without dividing the pulmonary ligament. The esophagus is separated from its bed by finger dissection and the nerves are identified and dealt with as described for the abdominal approach. The mediastinal incision is accurately closed with interrupted No. 60 cotton sutures. Interrupted sutures are used to unite the incised intercostal muscles together with the parietal pleura. Air is expelled from the pleural cavity by means of a watersealed catheter left in the wound until the last pleural suture is placed. The divided extracostal muscles and skin are closed in layers.

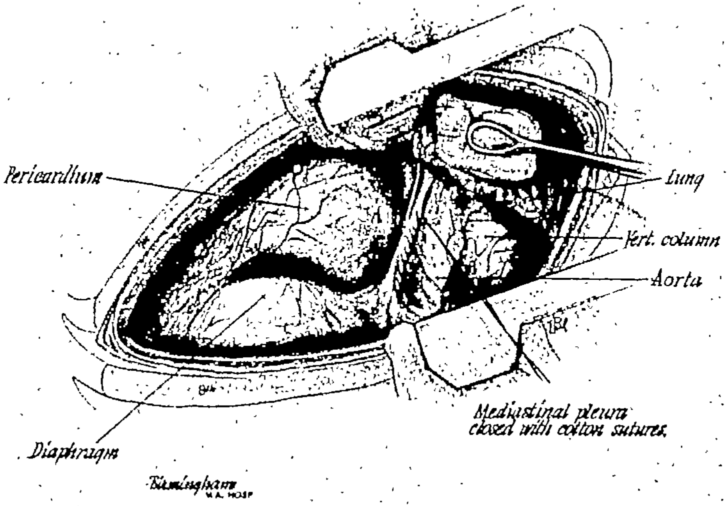

Fig. 8.—Accurate closure of mediastinal pleura with interrupted sutures.

POSTOPERATIVE CARE

The postoperative care is essentially the same for both procedures. The patient sits on the edge of the bed on the afternoon of the day of operation and is gradually ambulatory from then on. Wangensteen suction is used continuously for at least three days and longer in those cases in which severe distention persists. A surgical liquid diet is given on the fifth day and is changed to a surgical soft diet on the eighth day. Water, salt, vitamins and amino acids, sodium chloride, and glucose are given intravenously during the period of intubation. Small frequent feedings with a balanced diet are given as soon as the tube is removed. Patients with gastroenterostomy remain on a liquid

There was one death with the abdominal approach, due to postoperative pneumonitis. Fifty-six of the sixty patients undergoing vagus nerve section have experienced complete symptomatic relief. It should be taken into consideration that fifteen of the sixty patients had a gastroenterostomy performed in addition to the denervation. In four, the anastomosis was performed subsequent to vagus nerve section because of persistent pyloric obstruction.

There were two failures with the abdominal approach. They are reported here.

S. H., aged 40 years, had a vagus nerve section for treatment of a gastrojejunal stomal ulcer. After the operation he believed himself to be only "50 per cent relieved" and he still has frequent attacks of epigastric pain and vomiting. The acidity, which was not high before operation, remains unchanged. Roentgenologic examination has not been informative.

H. C. was a patient aged 42 years. An inflammatory lesion at the junction of the pylorus and duodenum was found at operation. Exposure was poor and the hiatal region was not well visualized. The cardia of the stomach was inadvertently opened during the finger dissection and was closed with intestinal suture. Two nerves, supposedly the right and left vagus nerves, were divided, but examination for other nerve segments was unsatisfactory. One year after operation there had been no improvement in the patient's condition.

There was one failure with the thoracic approach. The case is described here.

R. G., aged 36 years, began to have pain two months following discharge which was identical with that experienced before surgery. Studies of the insulin test and gastric motility indicated that vagal denervation of the stomach was incomplete.

Thus, there are three failures in the series; two with the abdominal approach and one with the thoracic. These are ascribed to incomplete denervation.

One case of erroneous diagnosis is worthy of special mention because of its bearing on the choice of operative approach. The patient had undergone a pyloric antrum resection elsewhere six weeks previously and experienced pain and hemorrhage following operation. Roentgenologic examination indicated a probable stomal ulcer but the evidence was inconclusive. Abdominal exploration revealed a localized abscess lying between the enterostomy and the transverse colon. Drainage of the abscess resulted in complete relief. Had the thoracic approach been used and vagotomy performed, the patient would have been classed as a failure, and it is even possible that a gastrojejunocolic fistula might have been formed.

In our early cases the operation was so much easier to accomplish through the thorax that we felt it should be used except in instances of pyloric obstruction, obscure diagnosis, malignancy either proved or suspected, or other abnormalities either known or suspected. However, with more experience and improvement in technique it was found that the denervation could be accomplished as satisfactorily with the abdominal approach, and we now use that method routinely. The advantages of being able to observe the lesion and perform gastrojejunostomy far outweigh the difficulties inherent in the abdominal approach.

the patient in swallowing and retaining the suction tube before operation has paid dividends in practically doing away with severe postoperative distention.

The patient with phlebothrombosis and pulmonary embolism was heparinized as soon as the complication was discovered and he made a satisfactory recovery.

COMPLICATIONS WITH THORACIC APPROACH

The postoperative complications with the thoracic approach are listed in Table II. Intercostal neuritis occurred in two patients. A segment of rib had been removed in one and a rib was fractured in the other at operation. Severe pain persisted for several months in the first, and for one week in the second. All of the patients with these exceptions have been remarkably free from pain following operation. The absence of intercostal neuritis is credited to the fact that most of the operations were done without costal resection.

TABLE II. POSTOPERATIVE COMPLICATIONS IN THIRTY PATIENTS WITH THE THORACIC APPROACH

COMPLICATION	NUMBER OF CASES
1. Intercostal neuritis	2
2. Pleural fluid (two severe with escape of fluid through wound)	5
3. Pneumonitis	2

Pleural fluid accumulated in large quantity in two cases, neither of which progressed to empyema. One of these patients had a large extrapleural abscess following the injection of Nupercaine in oil in the intercostal space. It is probable that the abscess together with trauma induced by dividing numerous dense pleural adhesions were the cause of the transudate. The practice of injecting the intercostal nerves has since been discontinued. The second patient had a massive accumulation of fluid in the left pleural cavity associated with an extensive bilateral pneumonia. Fluid in the other three cases was minimal and was absorbed spontaneously.

Pneumonitis was bilateral and extensive in one of the two cases and moderate in the other. The more serious case was one of those described as developing severe hydrothorax.

Summing up the complications, there were two cases of intestinal obstruction with the abdominal approach and none with the thoracic, two cases of pneumonia with the abdominal, one resulting in death, against two cases with the thoracic approach. There was one case of phlebothrombosis with the abdominal approach and none with the thoracic approach. Of the complications peculiar to each method, there were two cases of wound dehiscence and three of postoperative hernia of the abdominal wall; and two cases of intercostal neuritis and two cases of large accumulation of serous fluid in the pleural space.

CLINICAL RESULTS

The period of observation in both groups of cases is too brief to make an evaluation of the effectiveness of vagus nerve section in healing peptic ulcers. However, a review of the early results will aid in making a comparison of the merits of the two methods. In the comments which follow, all cases in which there has not been complete relief are counted as failures.

EXPLORATORY THORACOTOMY IN THE MANAGEMENT OF PLEURAL EMPYEMA

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Charlotte, N. C.

THE incidence of empyema in the pleural cavity has decreased since the advent of chemotherapy and the end of World War II. Empyema following lobar or lobular pneumonia is now rarely seen. Thus, empyema from hitherto unusual etiologic conditions is more commonly encountered in the practice of thoracic surgery. That which necessitates surgical treatment usually constitutes a complication of such conditions as bronchiectasis, trauma of the chest not associated with hemothorax, infected hemothorax, ruptured lung abscess, and ruptured subdiaphragmatic abscess, and as a consequence of tube drainage or too small rib resection in treating postpneumonic empyema.

I have the greatest respect for the time-tested surgical principle of draining an intrapleural abscess by tube insertion or rib resection; although in dealing with the type of case described here, such treatment alone in my experience usually has been inadequate.

Decortication of the lung has been recognized as sound management in acute, massive, or multiloculated pleural abscesses.[1] The mode of attack in present-day empyema, however, is being altered with the change in frequency of its underlying cause. It is now believed that an exploratory thoracotomy is indicated in any case of acute or subacute empyema of the pleura that does not satisfactorily respond to chemotherapy, aspiration, closed drainage, and general supportive measures. By means of this exposure it may be determined in each individual case which procedure to follow; whether decortication of the lung suffices, further surgery is indicated then, or surgery should be delayed for a subsequent operation. Illustrative cases will be presented and the problems and indications discussed for the surgical procedures which were chosen in each instance.

An exporatory thoracotomy can be done with safety only if the following conditions are fulfilled: (1) restoration and continuance of whole blood; (2) administration of large amounts of penicillin or streptomycin, depending upon the infecting organisms; (3) the availability of a competent anesthetist. With these protections almost no patient is too ill to withstand pulmonary surgery.

Each case is individualized in its management but comments will be made upon a few points of procedure. The trite but so important history cannot be overemphasized in trying to ferret out symptoms of a chronic pulmonary ailment such as productive cough and other symptoms suggestive of a pre-existing bronchiectasis. Roentgenograms of the chest are confined to anteroposterior and lateral views since stereoscopic films of the chest, in my opinion, are misleading.

From the Surgical Service of Charlotte Memorial Hospital.
Read (by title) at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

SUMMARY AND CONCLUSION

This early report on the results of vagus nerve section for the treatment of peptic ulcer in sixty patients is concerned chiefly with determining the relative merits and the indications for thoracic and abdominal approaches. *In our earliest cases the operation was easier to accomplish and the complications were less severe and less frequent when the operation was performed through the thorax.* As experience increased objectionable features of the abdominal approach were overcome and we now perform the operation routinely through the abdomen because of the advantages of being able to examine the lesion and perform gastrojejunostomy at the same time.

Performance of the operation of vagal denervation of the stomach should be preceded by a thorough acquaintance with the patterns and relative anatomy of the vagus nerves in the lower mediastinum.

An analysis of the results in our sixty cases suggests that failure to accomplish relief by vagus section should be ascribed to failure to perform the operation properly, or to faulty diagnosis.

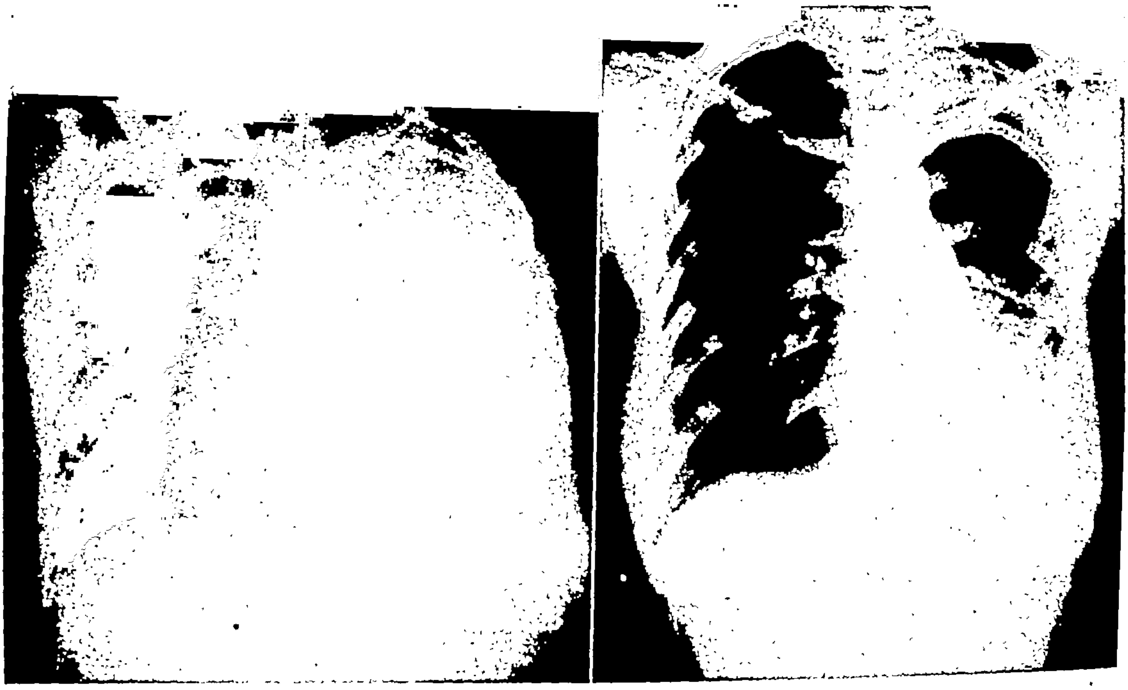
REFERENCES

1. Dragstedt, L. R.: Vagotomy for Gastroduodenal Ulcer, Ann. Surg. 122: 973, 1945.
2. Alvarez, W. C.: *An Introduction to Gastroenterology*, ed. 3, *New York, 1941, Paul B. Hoeber, Inc.*, p. 248.

the entire lung. The pus was evacuated and the lung was decorticated of its constricting sheet, after which it re-expanded satisfactorily.

In view of the fact that the lobe had re-expanded, it was thought undesirable at this time to proceed with lobectomy. A No. 32 mushroom catheter was placed in the eighth left interspace in the posterior axillary line and connected to a water-sealed jug. The patient received 1,500 c.c. of whole blood and 1,000 c.c. of glucose intravenously during the operative procedure. Bronchoscopic aspiration was done before the patient returned to her room.

Large doses of penicillin were continued. Ambulation was started the following day and the drainage tube was removed on the third postoperative day. On the fifth day the patient was afebrile and so remained during the subsequent stay in the hospital. She was discharged eleven days after the operation (Fig. 1, *B*).



A. *B.*

Fig. 1.—*A*, Note the displacement of the mediastinum to the right as air and fluid in the left have collapsed the left lung. *B*, Ten days after decortication note the re-expansion of the left lung, except for a small area in the apex, and normal position of the mediastinum.

She returned three months later for lobectomy. When this was done, surprisingly few adhesions between the visceral and parietal pleura were found, although the lobes were firmly adherent. The postoperative course this time was without mishap and she was discharged from the hospital ten days after operation.

Comment.—The history of pre-existing bronchiectasis and the sudden onset of the patient's illness with pain, dyspnea, and toxicity caused one to assume that a rupture of a bronchiectatic abscess had occurred. Tube drainage failed to reduce the symptoms and the temperature rose to 105° F. A thoracotomy was then performed. An incarcerated lung was liberated by decortication and the lung was inflated. Therefore, it was thought wise to delay resection for a later date whereby the extent of the disease could be demonstrated more accurately. The lower lobe was removed three months later. The patient, now symptom-free, is with her soldier husband in Alaska.

The chest fluid is aspirated and examined bacteriologically, preferably prior to antibiotic or chemotherapy. If this is not possible, para-aminobenzoic acid or penicillinase, respectively, is added to the culture media.

Hematologic examinations invariably include hematocrit readings. Blood transfusions are given until the hematocrit reading has reached a level of 50 or above. An intercostal tube may be placed into the empyema pocket and connected to a water-sealed jug resting upon the floor.

This latter procedure, however, is merely preliminary to the definitive treatment which follows after the cell volume has been restored to normal and after bronchography and bronchoscopic examinations in certain cases have been made. Bronchograms of the involved side are not omitted when there are suspected pulmonary communications into the pleural cavity or when there is suspected bronchiectasis which may warrant extirpation of the lobe or segment involved.

Under endotracheal anesthesia and continuous intravenous blood infusion an exploratory thoracotomy is undertaken. It is important that the infusion should be given simultaneously into two veins in order to sustain adequate blood volume. If the empyema is extensive, it is explored routinely through the fifth or sixth rib bed; otherwise, it is opened through a selected rib bed directly over the pocket. The pus is evacuated and decortication is carried out as previously described.[1] The lung is re-expanded if possible but when extensive bronchiectasis exists or when a lung abscess or malignancy is demonstrated, it may be advisable to delay extirpation surgery to a later date. In certain instances, however, it is preferable to remove the involved lung or segment in one operation.

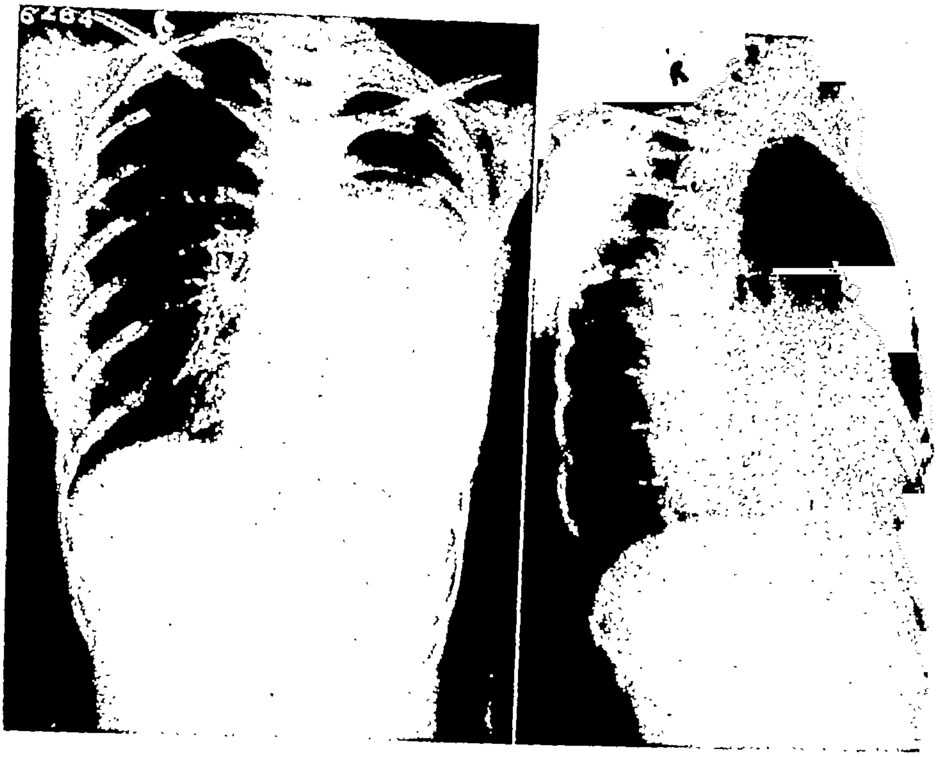
TYPICAL CASES OF EMPYEMA RESULTING FROM BRONCHIECTASIS

CASE 1.—B. P., a white, woman patient, 21 years old, was admitted to the hospital on Jan. 18, 1946, with the chief complaint of a sudden onset of a severe, knifelike pain in the left side of the chest, of forty-eight hours' duration, associated with chills, fever, and dyspnea. She had a history of having had bronchiectasis in the left lower lobe of several years' duration. The diagnosis had been established previously in another hospital.

On examination she appeared mildly cyanotic, acutely ill, and in marked respiratory difficulty. The temperature was 103.6° F., pulse was 120 beats per minute, and respirations were 34 per minute. The trachea was grossly displaced to the right (Fig. 1, *A*), the maximum impulse of the heartbeat was to the right of the sternum, and there was dullness throughout the lower left side of the chest and hyperresonance over the apex.

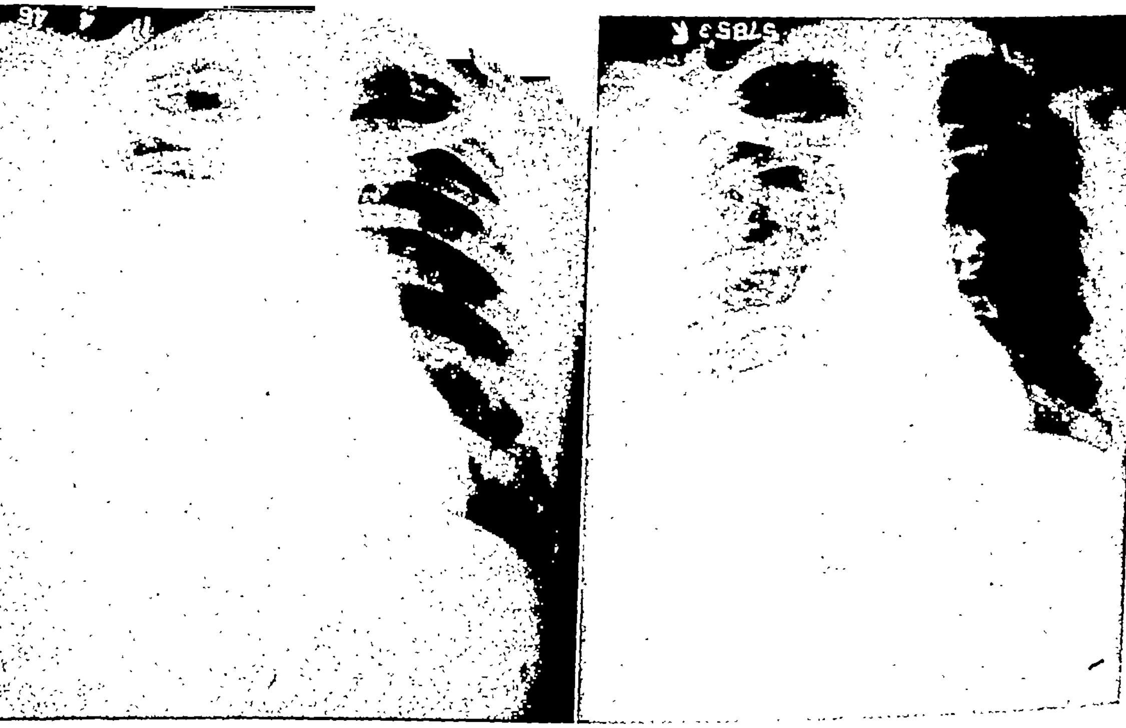
A catheter was placed in the eighth left interspace in the posterior axillary line. A turbid fluid was drained, from which alpha streptococcus and nonhemolytic *Staphylococcus aureus* were cultured. Penicillin, 50,000 units, was administered intramuscularly every three hours. The hematocrit reading was 41 and the patient was given a transfusion of 500 c.c. of blood. The temperature ranged from 101 to 104.6° F. The catheter did not drain satisfactorily and it was reinserted at another site where it also ceased to drain after a few hours. The patient's condition was not improved. Bronchoscopic examination was essentially unrevealing.

On the third day after admission, an exploratory thoracotomy was performed, excising the left sixth rib, under endotracheal anesthesia. Multiloculated empyema pockets and organized fibrin were found upon entering the pleural cavity. A thick capsule incarcerated



A. *B.*

Fig. 2.—*A*, This shows an area of density on the left that reaches to the second interspace anteriorly and a clear right lung with normal lung mappings. *B*, Semi-oblique views are more informative in revealing bronchiectatic changes with lipiodol in the presence of pleural exudate.



A. *B.*

Fig. 3—*A*, This film reveals an area of density that occupies the majority of the right pleural cavity with fluid level at the first interspace anteriorly. The remainder of the right chest cavity is filled with air. There is no noticeable displacement. *B*, This discloses satisfactory re-expansion of the entire right lung with an elevated diaphragm. Patient was symptom-free and returned to work four weeks later.

A case of similar clinical record was found on Dr. Edward Churchill's service at the Massachusetts General Hospital. This individual was treated by tube drainage but a pneumothorax developed which collapsed the lung. It is interesting to note the lack of organized adhesions that should have prevented this collapse. It has been suggested that early administration of penicillin may have played some role in nature's not forming normal adhesions.[3] However, I have not observed any lack of organized fibrin even though some patients had had large quantities of penicillin immediately after the onset of their illnesses.

CASE 2.—R. G., a 16-year-old, white female, was admitted to the hospital on Jan. 2, 1947, with the chief complaint of chills, fever, and a persistently draining sinus in the left side of the chest of three months' duration. She had a history of intermittent cough and fever, diagnosed as "bronchitis" in early infancy. Two years before admission she had "lobar pneumonia." In the fall of 1946 she had been hospitalized six weeks after a sudden attack of pleural pain followed by empyema, for which a rib resection drainage had been done. Temporary improvement had occurred, although the cough had persisted with elevation of temperature, and pus had continued to drain from the thoracic sinus.

Three months later she was transferred to the chest service. At this time the temperature was 102.4° F., pulse rate was 110 beats per minute, and respirations were 24 per minute. She appeared chronically ill, underweight, anemic, and apprehensive. Further examination showed that the trachea was in midline and that there was a lag on inspiration over the left side of the chest. There was signs of consolidation over the entire left side of the chest with the exception of the apex (*Fig. 2, A*). A draining sinus in the left posterior axillary line in the seventh rib area was seen. Cultures from this exudate showed a mixed infection of alpha and gamma streptococci, *N. catarrhalis*, *Diplococcus pneumoniae*, and nonhemolytic *Staph. aureus*.

Since the hematocrit reading was only 30, she was given 1,000 c.c. of citrated blood. Lung mapping demonstrated bronchiectatic changes in the entire left lower lobe, lingula, and base of upper lobe (Fig. 2, *B*). Penicillin aerosol (100,000 units diluted in 2 c.c. of saline solution) was carried out three times daily for three days. Bronchoscopically there was no obstruction to the left bronchus; only excessive exudate was seen.

On the fourth day after readmission the patient was prepared for an exploratory thoracotomy. The old sinus tract was excised in exposing the sixth rib. The pleura was very thick and its cavity was divided into pockets filled with purulent exudate. The lung was found to be constricted by a very thick, organizing, vascular sheet of fibrin. The lung was freed of its imprisonment but the lobes would not re-expand due to chronic atelectasis and bronchiectasis. Because of this it was determined necessary to proceed with a pneumonectomy. Bleeding was quite a factor but the blood volume was sustained by 2,000 c.c. of blood flowing in an arm and ankle vein. At the close of this procedure the chest was thoroughly irrigated with large quantities of saline solution, and 100,000 units of penicillin were instilled. A No. 30 mushroom catheter was inserted in the eighth left interspace. She withstood the operation well and returned to her room in good condition. The following day the hematocrit was 54. The customary postthoracic surgical care was given.[3]

The postoperative course was uneventful and recovery was rapid. Twenty-four hours after operation she was out of bed and the catheter was removed eighteen hours later. At no time following surgery did the temperature rise above 99.6° F. She was discharged eleven days after operation. This patient was seen four weeks later at which time she was afebrile, free of cough, and had gained weight. It was expected but, peculiarly enough, not until two months after pneumonectomy did this patient develop signs and symptoms of pleural infection; but the wound was uninvolved. The pocket, which was relatively small, was successfully collapsed by a one-stage thoracoplasty.

An exploratory thoracotomy was done through the right sixth rib bed on the third day after admission. The pleural cavity was found to be filled with a purulent, nonodorous, pasty, brownish exudate. After decorticating and re-expanding the lung, no bronchopleural fistula could be demonstrated though the communication through the diaphragm was easily identified. This led to a subdiaphragmatic and liver abscess. Through another incision, a segment of the right eleventh rib was resected and an extrapleural communication was made into the subdiaphragmatic abscess cavity into which two cigarette drains were inserted. Thereupon the perforation of the diaphragm was débrided and closed with interrupted silk sutures. The patient withstood the operation very well. The systolic pressure did not fall below 90 mm. Blood, 2,000 c.c., was given to sustain the patient during this surgery. Two large mushroom catheters were inserted in the chest cavity, one in the second intercostal space in the anterior axillary line and the other in the eighth interspace in the posterior axillary line. Suction was applied to the anterior catheter for a period of twenty-four hours, after which it was removed. The posterior catheter was irrigated daily for five days, then removed.

Routine care was followed, which in this case necessitated intercostal nerve blockings on three occasions. Emetine therapy was begun. On the fourth postoperative day the patient developed some asthmatic symptoms which were relieved by aminophylline suppositories.

The patient was afebrile on the third postoperative day and remained so until discharge from the hospital fourteen days after operation. Examination two months later showed a satisfactory re-expansion of the right lung (*Fig.* 3, *B*). The patient returned to his duties as cotton mill worker nineteen days after discharge from the hospital.

Comment.—In this individual, by having a large thoracotomy opening it was possible to estimate accurately the extent of the damage, decorticate the lung (thereby re-expanding it), and more easily drain the subdiaphragmatic abscess as well as close the communication between the chest and the abdomen. Such could not have been accomplished unless there was a large thoracotomy opening. Hospitalization was reduced many days as the patient returned to his former occupation thirty-three days after operation.

BRONCHIAL-RENAL FISTULA

CASE 4.—E. B., a 31-year-old white housewife, was seen in consultation on her second admission to the hospital when she was complaining of chills, fever, and a productive, foul cough of six days' duration.

On the previous entrance two months before there had been a diagnosis of right renal calculus, pyelonephrosis, and empyema in the right chest (Fig. 4, *A*). She was treated with repeated chest aspirations, penicillin, and other supportive measures. On this regime the patient improved. After eighteen days she went home for further improvement preparatory for a kidney operation.

The course at home was indifferent until ten days before admission, when a severe pain in the right shoulder region developed, associated shortly afterward with chills, fever, and paroxysmal attacks of coughing. The cough soon became productive with copious quantities of foul-smelling, reddish material. Coincidental with this the pain in the right shoulder disappeared although the chills, fever, and cough continued. The latter was made worse when she lay on the left side. The temperature ranged up to 104° F., pulse was 120, respirations 22, white blood cell count 18,000, and hematocrit 36.

On further examination she did not appear as ill as her vital signs disclosed. There was a slight lag on the right on inspiration. Breath sounds were distant throughout the right side of the chest. The percussion note also was impaired. Dullness in the right base was thought to be due to an elevated diaphragm. There was moderate tenderness in the kidney region but no tenderness over the liver could be elicited.

Comment.—Recognizing the rarity of ordinary empyema, an attempt is made to be alert to the unusual origin of this disease. Previously a bronchoscopic examination had been done but it failed to disclose any pathology. The referring physician surmised bronchiectasis when the cough persisted and improvement did not follow drainage of the empyema pocket. This case illustrates the justification of using lipiodol though we take the risk of creating or aggravating pneumonitis. It is also pertinent to note the extensive surgery done "through pus" without resultant acute pleural infection which may have been unwise, but it was felt that "our hand was called" when expansion of the lung after decortication was unsuccessful. The criteria in determining the need for resection of the part involved is whether or not the lobe or segment will expand under positive pressure or deflate with the release of same.

In that this youngster had already run the gamut of conservatism, it was felt justified to try to complete the surgery in one operation although weeks later the pleural space did become clinically infected. A remarkable improvement has been that of her mental attitude, which is important at the age of 16 while entering adulthood. She is now symptomless two months after thoracoplasty.

EMPYEMA AS COMPLICATION OF SUBDIAPHRAGMATIC ABSCESS

CASE 3.—C. C., a 23-year-old former sergeant, was admitted to the hospital by ambulance on Oct. 31, 1946, with the chief complaint of fever and pain in the right side of the chest, associated with generalized malaise. He had a history of persistent diarrhea, with stools containing blood and mucus, of two months' duration in 1943 while on military duty in Africa. With the exception of dysentery, he had no illness until approximately six weeks prior to admission when he suffered "an attack of pneumonia," involving the right lung. He apparently responded well to chemotherapy for three weeks, after which he developed intermittent fever associated with "a tired, worn-out feeling." Shortness of breath on exertion and a slight, nonproductive cough were also complaints.

When examined, he was a well-developed white man, acutely ill, listless, and moderately short of breath. Temperature was 102.6° F., the pulse rate was 108 beats per minute, and respirations were 28 per minute. The trachea was to the left since the right chest did not expand normally on inspiration. There were signs of air in the right apex and fluid in the right base. The heart was not remarkable. The left lung fields appeared clear. It was impossible to palpate the liver, although there was tenderness to fist percussion in the liver area. The muscles were somewhat splinted in the right upper quadrant but no rebound tenderness was noted. No viscera or masses could be felt. The laboratory findings showed a red cell count of 3,800,000 per cu. mm. and a white cell count of 20,200 per cu. mm. The hematocrit reading was 36.

The right side of the chest was aspirated and 500 c.c. of tenacious, anchovy-like material were withdrawn. Routine smears and cultures failed to reveal any organisms but numerous pus cells were found. X-ray examination of the chest, anteroposterior and lateral views, showed a hydropneumothorax on the right side with two fluid levels and a slight shift of the mediastinum to the left (Fig. 3, *A*).

Whole blood, 1,000 c.c., was given immediately and Demerol, 50 mg., was needed repeatedly for the control of pain in the chest. Further therapy consisted of 50,000 units of penicillin every three hours. The stools were negative for *Amoeba histolytica* as were the cultures and smears from the chest fluid. Bronchography showed no bronchiectasis or bronchial communication through the diaphragm. A preoperative diagnosis was made of empyema resulting from a ruptured subdiaphragmatic abscess thought to have been secondary to abscess of the liver, questionably of amoebic origin.

There was demonstrated a bronchopleural communication beneath the diaphragm as evidenced by the same character of fluid there obtained as the patient coughed; and by bronchograms and lipiodol injections it was possible to demonstrate "puddles" of the opaque substance below the diaphragm in the region of the right kidney (Fig. 4, *B*).

Bacteriologically, gram-negative rods and alpha streptococci were cultured from the sputum and aspirated exudate. The patient was given 1,000 c.c. of whole blood prior to surgery. Six days after admission the eleventh and twelfth ribs were resected subperiosteally through which a large abscess cavity was encountered in the subdiaphragmatic area. This cavity was partly filled by a large, ruptured, pyelonephrotic, right kidney. After decompressing the abscess the diaphragmatic fistula could not be identified. The kidney was removed in a subcapsular manner.* Cigarette drains were inserted and the wound closed in anatomic layers. During the operation the patient received four pints of blood and 1,000 c.c. of glucose.

The postoperative course was satisfactory. The temperature did not exceed 100.4° F. Early ambulation was started and the patient was discharged two weeks afterward with a small No. 14 catheter in place. Roentgenograms then showed an elevated diaphragm but relatively clear chest cavity. The cough had stopped and there were no symptoms suggestive of the bronchial fistula being open. The patient was seen again four weeks after operation and she was free of respiratory symptoms (Fig. 4, *C*).

Comment.—Pleural infection and a diaphragmatic bronchial fistula, secondary to a pyelonephrotic kidney, cause one to respect the bizarre origin of present-day empyema. Would the morbidity and hospitalization have been appreciably reduced if an exploration had been made on the first admission to the hospital two months previously?

TRAUMATIC EMPYEMA

CASE 5.—F. H., a 32-year-old white man, was admitted to the hospital on Jan. 2, 1946, because of increasing difficulty in breathing, with chills and fever of twelve days' duration. He gave the story of having "been in a fight and sustained a knockout blow on the right chest" some seventeen days previously. Apparently no evaluation of intrathoracic involvement had been made at that time.

At physical examination he appeared acutely ill and rather pale. Breath sounds were absent, percussion note was dull over the posterior base of the right chest, and no scars were seen (Fig. 5, *A*). Aspiration obtained a thick, turbid material that grew a mixed culture of cocci and bacilli. Temperature was 103° F., pulse rate 116 beats per minute, and respirations were 30 per minute. Penicillin in large doses had been given prior to admission and this was continued in 50,000 units every three hours. As the hematocrit reading on admission was 30, he was given 1,500 c.c. of whole blood. Repeated attempts at aspiration of the chest obtained a very small amount of thick pus. Temperature ranged from 101 to 105° F. The white blood cells numbered 21,000 per cu. mm. The urinalysis was negative.

An exploratory thoracotomy was done on the right side with resection of the seventh rib. The chest cavity was filled with organizing, foul-smelling exudate. The posterior and lateral portions of the lower lobe were partially compressed, being held with a constricting sheet of exudate. This was removed, thus allowing the lung to re-expand and fill the previously existing empyema cavity. A No. 20 mushroom catheter was placed in the eighth interspace in the posterior axillary line. The patient received 2,000 c.c. of whole blood during the operation. Penicillin therapy was continued.

Progress was uncomplicated. The temperature subsided on the fifth postoperative day to normal and so remained. The drain was removed seventy-two hours after operation. The patient was discharged with the lung re-expanded and in good condition on the tenth day after surgery (Fig. 5, *B*). He has remained free of respiratory symptoms to date.

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*By Dr. Roberts McKay.

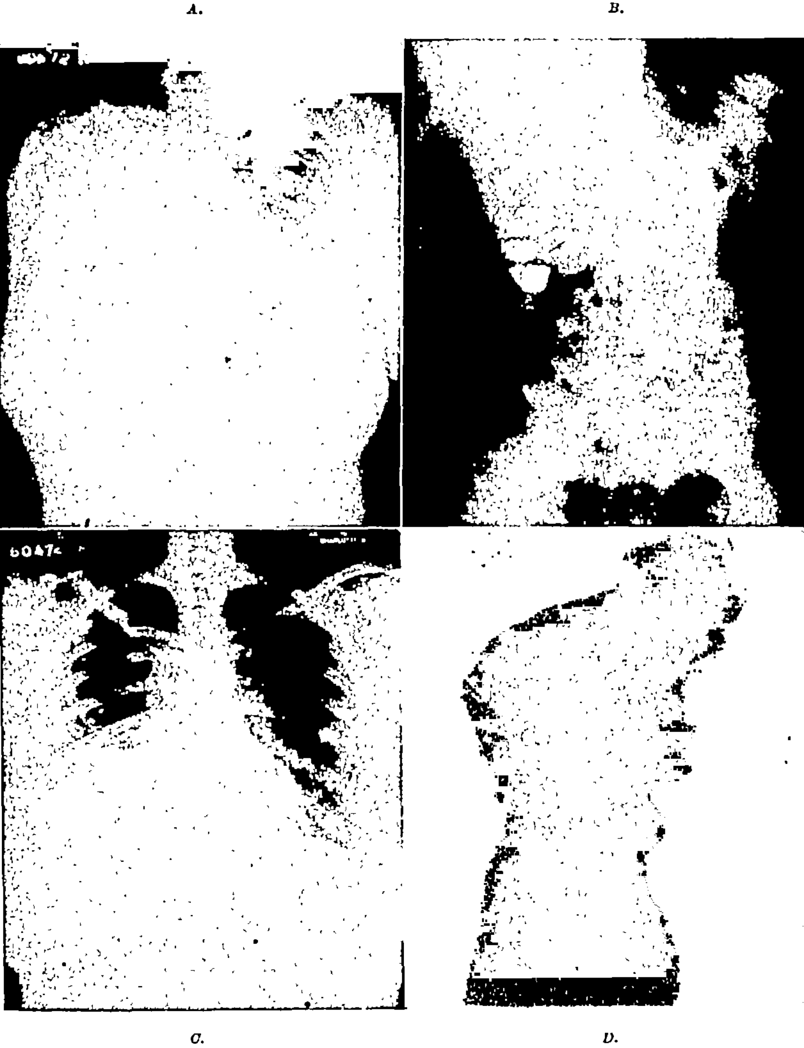


Fig. 4.—*A*, Anteroposterior view shows a homogeneous blurring of the lower two-thirds of the right pleural cavity. Empyema in this instance was secondary to subdiaphragmatic abscess. *B*, Bronchograms and injection of lipiodol into abscess cavity disclosed "puddling" of the opaque substance, which indicated a bronchial-renal fistula and at operation disclosed communication into a pylonephrotic kidney. *C*, Shows satisfactory clearing of the right lung although the diaphragm remains elevated. Four weeks after drainage of the subdiaphragmatic abscess and nephrectomy, the bronchial fistula had closed and patient was free of all respiratory symptoms.

Comment.—The presumptive cause of this patient's empyema was a traumatic, infected, organized hemothorax. Such being the case a bronchoscopic examination and bronchograms were not indicated, although at operation no evidence of organized hemothorax was apparent. Here we were dealing with a localized empyema pocket and by making the incision longer and excising slightly more rib than usual, the cavity was emptied of its pus. Under visualization, with adequate exposure the lung was decorticated and re-expanded, which allowed the cavity to be filled with a useful, healthy lung. The intercostal tube was removed three days after operation. The patient was discharged on the tenth postoperative day. This is in contrast to the usual way of treating empyema pockets, that is, insertion of a tube or resection of a small segment of a rib. The majority do recover, but such a patient treated by the latter method usually remains in the hospital more than two weeks with uncomfortable drainage of pus from the tube or sinus. Furthermore, daily dressings are always necessary. Aside from the economical, physical, and mental considerations, it seems to be false conservatism to prefer an inadequate exploration of these empyema cavities. In short, it is felt that this case gives support to the theory that more extensive surgery in individuals with large or even small empyema cavities is actually the conservative measure.

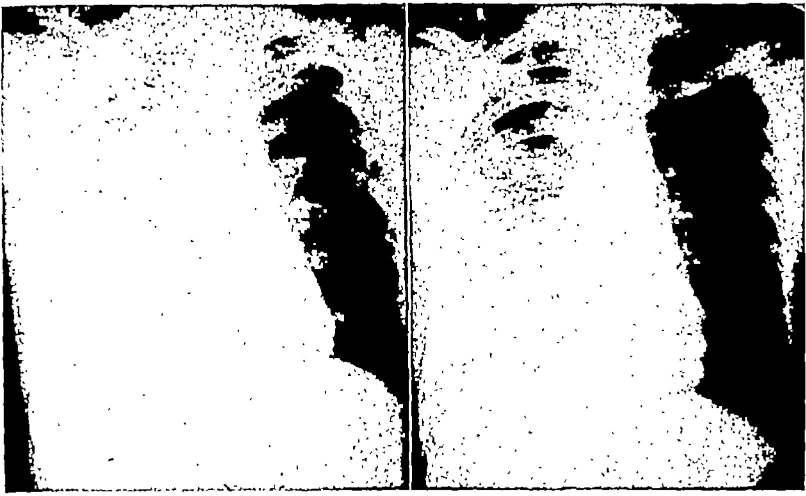
INFECTED ORGANIZED HEMOTHORAX

The next two cases represent clear-cut problems.

CASE 6.—C. S., a 48-year-old, white woman, was admitted to the hospital on Feb. 25, 1946, complaining of pain in the anterior right part of the chest following a stab wound three weeks previously. The patient was slightly dyspneic and the temperature ranged from 101.6 to 104.6° F. The pulse was rapid, around 112 to 120 beats per minute. She was anemic, with a red blood count of 2,900,000 cells per cu. mm. and a hematocrit reading of 31. Pertinent findings of the right chest were dullness to percussion and absence of breath sounds (Fig. 6, *A*). A thoracentesis yielded a dark, thick, bloody fluid which was negative on smear, although it had a putrid odor. No organisms, however, were grown on culture. Penicillin had been given previously. It was reinstituted and she was given 1,200 c.c. of whole blood.

On the second day after admission, an exploratory thoracotomy was done through the right sixth rib and there the chest was found to be filled with an odorous, organized, infected hemothorax. The lung was decorticated and allowed to re-expand. A No. 32 catheter was placed in the eighth interspace and connected to a water-sealed jug. The patient had an uneventful postoperative course and was out of bed twenty-four hours after operation. She was afebrile on the fifth postoperative day. Ten days after operation the patient was discharged (Fig. 6, *B*). She returned to her work as a seamstress three weeks later and has remained well since that time.

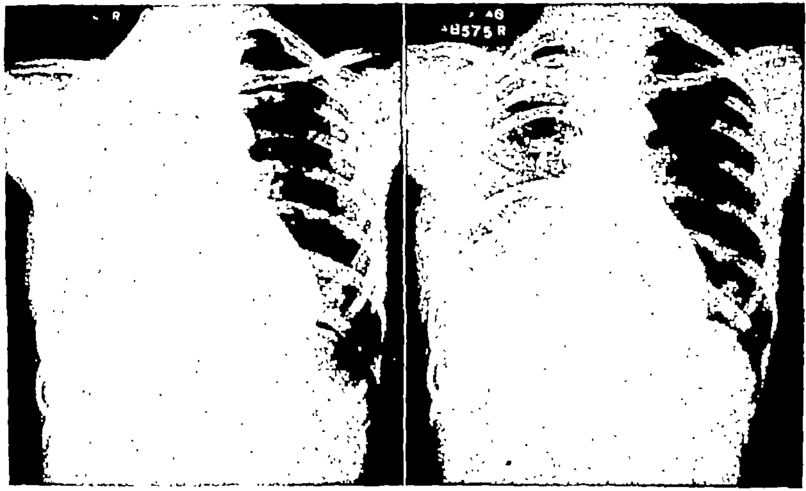
CASE 7.—W. M., a Negro man, 40 years old, was admitted to the hospital on Feb. 10, 1946. He gave a history that approximately nineteen days previously he had been stabbed from behind by an unknown assailant. There had been shortness of breath immediately and profuse bleeding. The wound had been sutured eight hours later in a distant hospital. Presumably the wound did suck. The patient's physician aspirated 1,500 c.c. of blood from the left side of the chest, and in subsequent aspirations 600 c.c. and 1,000 c.c. were drawn on successive days. After that no further fluid was obtained and he was given no supportive blood, although he did receive penicillin. For nineteen days the patient remained short of breath. Chills and an elevation of temperature which ranged around 104° F. developed.



A.

B.

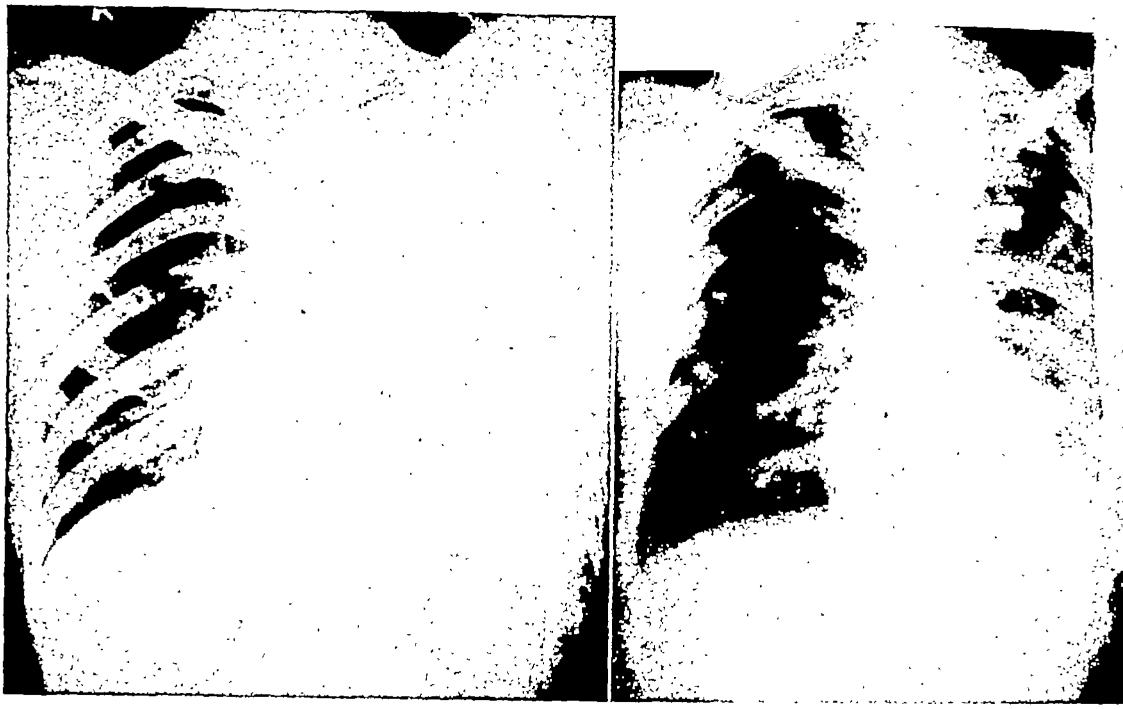
Fig. 5.—*A*. There is an isolated empyema pocket localized in the posterolateral region which was explored through the right sixth rib. The cavity was evacuated and the lung was decorticated. *B*. This shows very satisfactory re-expansion of the lung and elimination of the empyema ten days after operation.



A.

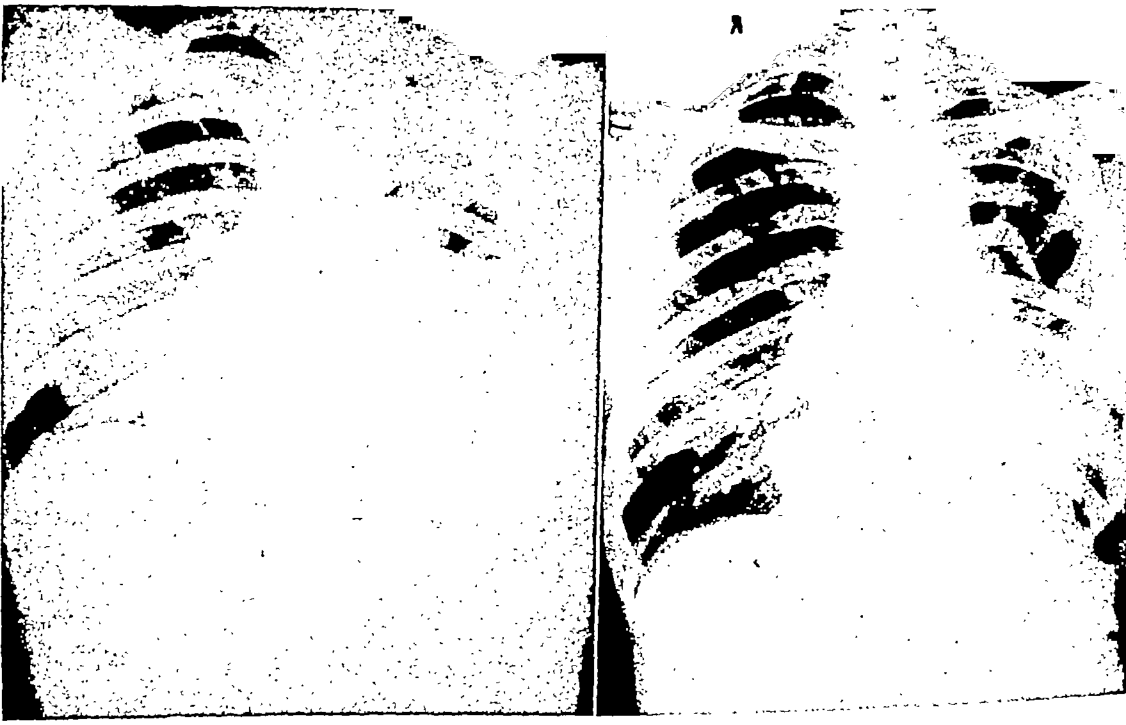
B.

Fig. 6.—*A*. The right lung is obliterated, which proved to be caused by organized, foul, infected hemothorax. *B*. Fourteen days after operation the right lung is re-expanded. The semi-density along the margin of the pleura is interpreted to be that of organized fibrin on the parietal pleura, which was not thought necessary to remove at the time of decortication.



A. B.

Fig. 7.—*A*, This film shows a homogeneous density over the entire left lung field. *B*, Eight days after an exploratory thoracotomy, when the pus was evacuated and decortication effected, it is noted that the lung has completely re-expanded and there is no residual fluid in the pleural cavity.



A. B.

Fig. 8.—*A*, Air and fluid have completely compressed the left lung and displaced the mediastinum to the right. *B*, This film, made seven weeks after operation, demonstrates a re-expanded left lung and elevated diaphragm.

When admitted to our hospital he was poorly nourished, pale, dyspneic, and perspiring freely. The trachea was in the midline. The chest was symmetrical with a definite lag on the left. The right lung field was relatively clear. The left was dull to percussion over its entirety. The abdomen was peculiarly spastic and tender in the left upper quadrant; however, there was no rebound tenderness. The hematocrit reading was 28. Hemolytic staphylococcus and *Bacillus coli* were cultured from the aspirated fluid. X-rays of the chest (Fig. 7, *A*) showed homogeneous density over the entire left lung field. The lateral film showed air anteriorly and a fluid level posteriorly. Aspiration obtained 1,500 c.c. of air and only 500 c.c. of purulent, offensive, bloody material were drawn from the left posterior eighth interspace.

The patient was given 1,000 c.c. of blood preoperatively and prepared for an exploratory thoracotomy which was done two days afterward through a section of the left sixth rib. The lung was encased and the thoracic cavity filled with an organized, infected hemothorax. Decortication was carried out in the usual manner. Bleeding was quite annoying. The patient was supported on 1,500 c.c. of blood and 1,000 c.c. of plasma. Two catheters were used, one in the anterior second interspace and one in the posterior axillary line in the eighth interspace.

He had an uneventful postoperative course and was allowed out of bed on the second day. The catheters were removed on the second and fourth days, respectively, after the operation. He was afebrile forty-eight hours postoperatively and so remained until discharge eight days after surgery (Fig. 7, *B*). He returned to his occupation as a chauffeur three weeks after leaving the hospital.

Comment.—These two cases are typical of the badly infected, organized hemothorax which notably is the type that experience in World War II taught us could be decorticated with impunity[4]; otherwise the patient would likely become a pulmonary cripple unless the lung was freed, thus allowing it to reexpand and fill the pleural cavity. It is a matter of record that these soldier patients, for the most part, were readily restored to useful military duty within a period of a few weeks.

PNEUMOPYOTHORAX AS RESULT OF INADEQUATE SURGERY IN POSTPNEUMONIC EMPYEMA

CASE 8.—J. M., a 40-year-old, colored man, was seen at the hospital in October, 1946. The chief complaint was a productive, foul cough, "lung abscess," and an abdominal hernia of ten months' duration. He gave a story of having had a "gall bladder operation" ten months previously. During this stay in the hospital he developed pain in the left chest, shortness of breath, and an elevation of temperature. A diagnosis of pneumonia on the left side, complicated by empyema, was made. The old record showed that the chest cavity was drained by rib resection and insertion of a tube, but his shortness of breath and pain in the chest with drainage of excessive pus, chills, and fever continued after discharge from the hospital. Soon after going home he developed a large postoperative hernia in the right upper rectus incision.

Upon examination he was found to be a poorly nourished, colored man who sat propped up in bed, continuously holding the sputum cup because the cough was most persistent. The mediastinum and trachea were displaced to the right. He did not use the left side in breathing. There were three sinus tracts in the left axillary draining very putrid-smelling, creamy exudate. As he coughed, large quantities of this offensive drainage spewed through these sinuses. Merely by compression of the chest and leaning to the left, the patient drained approximately 500 c.c. of such exudative substance.

The left lung was virtually obliterated. The left apex was filled with air and the base with findings of fluid (Fig. 8, *A*). There was a shift of the mediastinum to the right and increased peribronchial shadows in the right base. Another pertinent finding was a large,

4. This radical attack is justified only after (a) preoperative studies for the underlying pathology have been exhaustive; (b) the hematocrit reading is 50 or above with ample blood available for the operation; (c) penicillin, 50,000 units every three hours, or streptomycin, 2 Gm. daily, has been given pre- and postoperatively; (d) a competent anesthetist trained in endotracheal anesthesia is assured, which is one of the most important factors.

5. Representative case reports are given in an attempt to establish the indications for thoracic exploration, which in reality is conservative, by reducing the morbidity and preventing economical and psychologic bankruptcy.

6. In this series of pleural empyema there have been no deaths, and all have been fully rehabilitated in a relatively short time.

CONCLUSION

After intelligent conservative measures, it is my opinion that an exploratory thoracotomy is the treatment of choice in present-day pleural empyema, otherwise we are apt to be temporizing. If one chooses not to explore these cavities one must willingly accept the likely consequences of a long morbidity superimposed on the inconvenience of a drainage tube or a sinus tract that necessitates much care. It must be borne in mind that the compressed lung may never completely re-expand unless decortication is carried out. It is agreed, however, that in some incidences this is merely treating the effect of the underlying cause. Therefore, in certain individual cases, as with these, it may be expedient to extirpate the cause while treating the effect. Such decisions, though, are a matter of surgical judgment and cannot be determined by a slide rule.

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protruding herniation through the right rectus incision. Viscera and peristaltic movements could be felt and seen through a thin skin that was the only protection of the abdominal cavity. The mass, however, was reducible as nothing else abnormal was detected in the abdomen.

Penicillin therapy was given intramuscularly and by inhalation. Since the hematocrit reading was only 24, the patient received four transfusions. The hematocrit reading then rose to 51 (it is interesting that the first 1,000 c.c. of blood raised the hemoglobin, red blood cells, and hematocrit appreciably little). Lung mappings did not disclose any bronchopleural communication although it was certain such existed. Bronchoscopic examination uncovered excessive, odorous exudate coming from the left main stem bronchus which appeared compressed.

Five days after entrance into the hospital a thoracotomy was performed. The left sixth rib was excised along with the draining sinuses in this region. A portion of the seventh rib posteriorly also was removed. Upon entering the pleural cavity through a very thick pleura, it was found that the diaphragm was elevated and fixed. The purulent material was all aspirated. It was estimated that some 1,800 c.c. of exudative clumps of fibrin were evacuated. The lung was tenaciously bound down by a thick, organized capsule. This was carefully and laboriously removed. Bleeding was extensive but the lung re-expanded about 85 per cent of its normal extent. It was impossible to identify a bronchial fistula, which undoubtedly was there. During the operation the patient received 2,000 c.c. of whole blood and 1,000 c.c. of normal saline solution. A No. 26 French catheter in the second anterior intercostal space ceased to bubble on the third postoperative day and was removed. The posterior one, however, was left in place for seven days.

Ten days after operation, the ventral hernia was repaired with silk under general anesthesia and the postoperative course for this was satisfactory until twelve days afterward, when he developed an abscess in the incision of the repaired abdominal hernia. This complication prolonged the hospitalization another fifteen days. Two months later (Fig. 8, *B*) the patient was making his own living, working in an office.

Comment.—This case exemplifies an individual who, after ten months of suffering from a debilitating illness and with the inconvenience of pus continuously draining from his side, was rehabilitated by decortication. It is only fair to speculate that such a case could have withstood this same procedure originally, when the treatment of the empyema was inadequate for which reason it is felt that there is a place for exploratory thoracotomy in cases that do not readily react to conservative measures. Regardless of the size of the empyema, it seems that the patient should be given the advantage of an exploration for decortication, lobectomy, or pneumonectomy as the underlying condition may warrant. In some cases, however, it is prudent to delay any extirpative surgery for a later date.

SUMMARY

1. The incidence of empyema secondary to lobar and lobular pneumonia is now less frequent than empyema secondary to heretofore uncommon etiologic factors, such as ruptured bronchiectatic abscess, infected hemothorax, ruptured subdiaphragmatic abscess, traumatic empyema, ruptured pulmonary abscess associated with or without malignancy, and as a consequence of inadequate surgery for postpneumonic empyema.

2. The advantages of an exploratory thoracotomy in cases of empyema that do not satisfactorily respond to conservative therapy are emphasized.

3. The rationale of early decortication in empyema thoracis is reaffirmed.

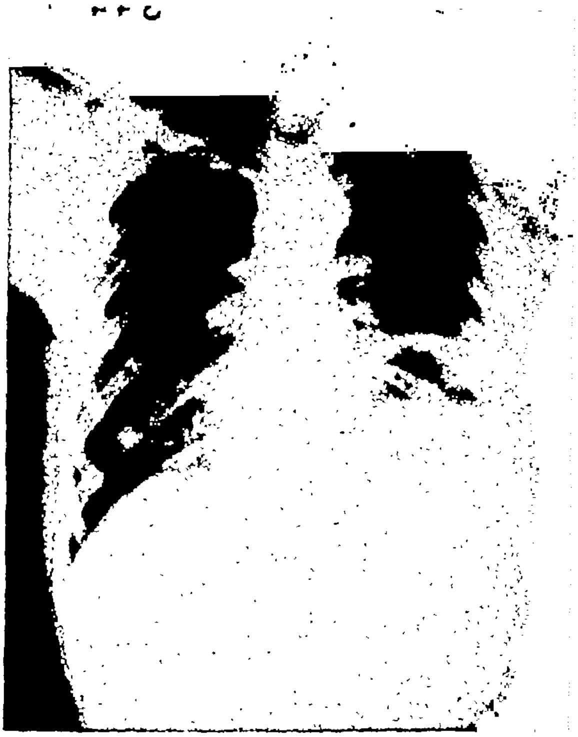

Fig. 1.—Upright chest roentgenogram taken on admission showing herniated viscus with suggestion of thickening of stomach wall.

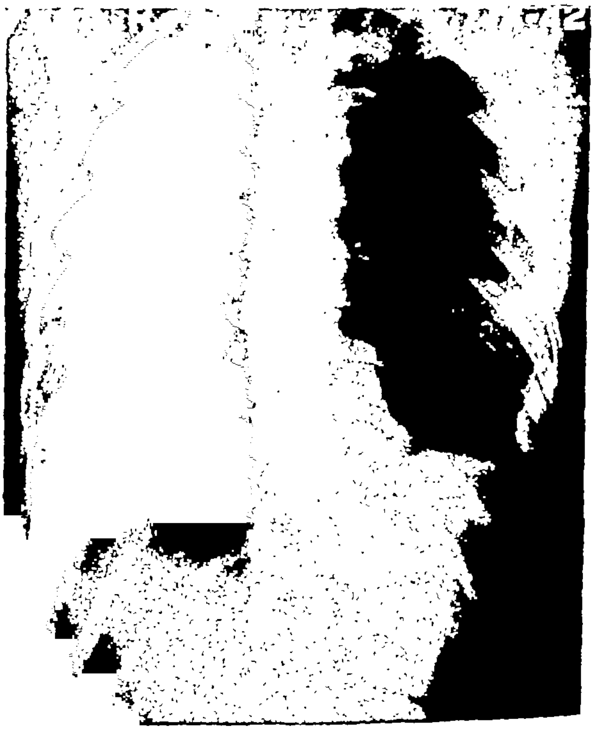

Fig. 2.—Barium swallow demonstrating complete obstruction at lower esophagus.

STRANGULATION OF THE STOMACH AND TRAUMATIC DIAPHRAGMATIC HERNIA

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THE majority of patients presenting a traumatic diaphragmatic hernia are relatively free of symptoms referable either to the respiratory or gastrointestinal systems. As a rule these individuals do not have the ulcer complaints and dietary discomforts which are characteristic of congenital or hiatal hernias. Diagnosis of the traumatic type is for the most part suspected on a routine chest film following a history of left-sided trauma, and confirmation is obtained by barium study of the gastrointestinal tract. Surgical repair of the diaphragm with the replacement of the abdominal contents is strongly recommended in the traumatic cases in particular, as the results are so satisfactory, and because of the danger of strangulation of the eviscerated bowel in the untreated cases. A review of the literature reveals that strangulation in an abnormal diaphragmatic opening due to trauma does not occur commonly, but when it does develop is of sufficient gravity to justify the over-all recommendation of surgery before such a complication occurs. For this reason it is felt that our cases are of interest both in their similarity and progress.

Two cases of traumatic diaphragmatic hernia with acute strangulation of the stomach are presented. In both instances the diagnosis was made preoperatively, surgical treatment was performed transthoracically, the stomach was the only abdominal viscus involved, and successful repair was obtained. Both cases occurred in young men in the military service, and were brought about following dietary indiscretion. In neither patient had the diagnosis of hernia been made prior to the acute illness. It is our purpose briefly to present the history, physical findings, and progress in these two cases with a review of the literature and reported cases to date.

Case 1.—This 24-year-old Mexican soldier was admitted to the 73rd Evacuation Hospital in Los Angeles on July 4, 1942, and shortly thereafter was transferred to Hoff General Hospital with the diagnosis of left traumatic diaphragmatic hernia. The history revealed that on July 3, 1942, following a long convoy ride and several glasses of beer, he became nauseated, vomited, and complained of sharp pains in the left lower chest and upper abdomen radiating to the left shoulder. This pain increased following vomiting and deep breathing. The past history was not contributory with the exception that on Oct. 14, 1940, he received a stab wound in the lower left thorax for which he was hospitalized in the Los Angeles County Hospital for about four days, following which he developed the sole complaint of considerable gas which was unaltered by food. The period of discomfort lasted nine or ten days and thereafter subsided completely. At the time of the hospitalization in 1940 no roentgen studies were taken. During the interval between the stabbing and the present illness there were occasional brief episodes of anorexia and nausea, but no vomiting. The

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Read (by title) at the Twenty-seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

attempt to do a resection would undoubtedly result in a fatality on the operating table. Following a fifteen-minute application of hot packs there was a further change in the color of the stomach wall and it seemed definitely improved. The organ was replaced into the abdomen without further manipulation and the chest was rapidly closed after crushing the phrenic nerve just below the pericardium. The chest was closed in layers without drainage. A roentgenogram of the chest taken three days following surgery showed complete re-expansion of the left lung and an elevated left diaphragm. Recovery was uneventful except for a high degree of atony of the stomach which occurred immediately following surgery. This complication was followed closely by gastroscopy and roentgenograms and improved slowly to the point of complete recovery within six months when the patient was returned to full duty.

CASE 2.—This 28-year-old soldier was admitted to Fitzsimmons Hospital on Jan. 26, 1946, having been ill approximately two weeks. Eighteen months before he had received a bayonet wound of the left lower chest and was hospitalized for three weeks. Roentgen studies of the chest were taken at the time of the injury and were not available.for comparison, but according to the patient no active treatment was necessary and he recovered rapidly without residual symptoms. He remained well until fourteen days prior to admission when, following the ingestion of a heavy meal, he became nauseated. The patient had no acute pain, but the nausea continued and he had intermittent vomiting attacks from then until admission to the hospital. He had been unable to take food of any kind for three days and the temperature was slightly elevated during the twenty-four hours prior to admission. On entry the patient had a temperature of 101.2° F., pulse 118, and respirations 24. He was complaining of severe epigastric pain which had commenced four hours previously and was accentuated on deep breathing. Flat films of the chest revealed herniation of the stomach, and barium studies showed complete obstruction. After fortifying the patient with intravenous fluids a left thoracotomy was performed. On entering the pleural cavity approximately 100 c.c. of clear amber fluid was encountered. The upper third of the stomach was in the pleural cavity and the fundic portion was rather densely adherent to the left lower lobe. The stomach wall was slightly hyperemic, but there was no evidence of serious interference with circulation. After enlarging the opening of the diaphragm the stomach regained its normal color promptly, was returned to the abdominal cavity, and repair was accomplished. The patient made a satisfactory recovery and was returned to full duty.

While these two cases bear a definite similarity to each other there are certain points on which there is considerable difference. Both individuals had practically the identical portions of the stomach involved, yet Case 1 was of shorter duration and represented a far more urgent surgical emergency. Case 2, as evidenced by the adhesions of the fundus to the left lower lobe, was probably slower in developing obstruction and the edema at the hiatal ring contributed to the general constriction. It is not without the realm of possibility that spontaneous reduction of the stomach might have recurred in the second case if surgery had been delayed, but such a development would have been most remarkable and certainly not to be relied upon. There is no doubt that surgery was a life-saving measure in the case of the individual first described, inasmuch as even manual reduction of the strangulation at the operating table was a difficult procedure.

Much has been written during the past several years on the general subject of diaphragmatic hernia, particularly with regard to the mechanics and physiology involved. In 1934 Hedblom[1] reported 1,408 cases of diaphragmatic hernia, mostly collected from the literature, of which 821 were congenital and 587 traumatic in type. In reviewing the literature on the subject of acute strangulapertinent physical findings on July 4 were an old stab wound scar in the ninth interspace on the left side of the chest in the posterior axillary line; slight diminution of expansion of the left lower part of the chest; and impaired resonance and dullness to percussion over the anterior lower left chest with flatness in the posterior area. There was moderate tenderness to palpation in the left upper abdomen, but no evidence of rigidity or peritoneal rebound tenderness. On the day of admission, July 4, 1942, an upright roentgenogram of the chest showed what appeared to be a hollow viscus, most likely stomach, in the left pleural cavity (Figs. 1 and 2). A barium swallow taken at the same time showed complete obstruction at the lower end of the esophagus (Fig. 3). The diagnosis of complete obstruction having been established the patient was prepared for surgery. Using a posterolateral approach the left chest was opened through the bed of the eighth rib. On entering the pleural cavity a large blue-black mass was immediately encountered which was apparently hollow viscus under great tension. This extended upward into the pleural cavity for approximately 25 cm. Rib spreaders were introduced and 250 c.c. of thin serosanguineous fluid having a definite musty odor was removed from the left pleural cavity. Careful exploration revealed that the mass described was strangulated stomach. No other organ was present in the thoracic cavity. Apparently the stoma of the ruptured diaphragm was relatively small and lay just mesial to the dome. Decompression of the stomach was attempted by having an assistant pass a stomach tube, and after considerable difficulty a large Ewald tube was passed beyond the hiatus into the stomach proper and aspiration of a large amount of foul thick bloody fluid and gas was effected. With the stomach collapsed it was apparent that the wall was considerably thickened and a Y-shaped incision in the diaphragm was necessary in order to return the organ to the abdominal cavity. This accomplished, the ribs were temporarily approximated and the lung re-expanded. At this time the patient's condition was very poor and a transfusion was commenced. The condition improved somewhat and the stomach was again brought into the pleural cavity. Careful examination indicated a slight change of color of the stomach wall with more of a purplish hue except in several small areas. Whether or not the organ was viable could not be determined accurately, but it was obvious that any

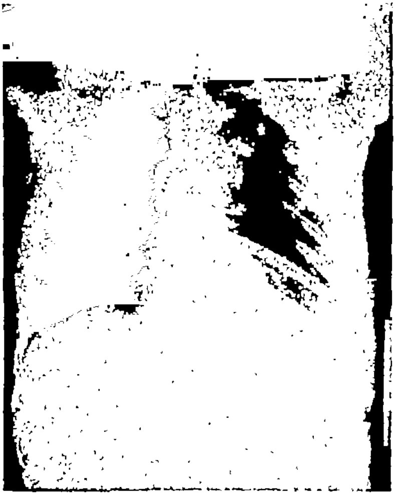

Fig. 3.—Upright chest roentgenogram taken three days following surgical repair of hernia.

given, but from the description of the diaphragmatic opening the supposition that the opening was traumatic in nature is probably justified. The authors quoted a statement by Knaggs made in 1904 with regard to the mechanism or physiology concerned in strangulation of the stomach which seems worthy of repetition even more than forty years later: "The ulceration that occurs in strangulation of the stomach seems to be different from ulceration and strangulation of the intestine. In the latter it begins in the mucous membrane surface and extends to the outer coats. In the case of the stomach the available evidence points to extreme distension, producing splits through the integrity of the sodden and rotten mucous membrane. Further ulceration does not appear to have been noted at the seat of constriction, the most common place for it in the intestine."

In considering the four cases reported, there are several factors which seem significant. There are doubtless other cases of this general nature which are not listed in the available records. Mortality for this series is 75 per cent. Three patients were treated by surgery and one was given supportive therapy. The one not operated upon died within two days after coming under observation and showed a gangrenous stomach at post-mortem examination. The sole surviving patient[4] was most unusual in that a strangulated diaphragmatic hernia was repaired on one occasion only to be followed by a recurrence of the exact mechanism three years later. In both instances successful repair was accomplished through a transthoracic approach. It is not so stated, but it is doubtful that serious interference in blood supply of the stomach was present on either occasion. The only patient operated upon who showed definite evidence of circulatory disturbance at surgery died. This patient was actually ill for four days and was operated on by the abdominal approach. In the third fatal case[2] the patient had been acutely ill for ten days prior to laparotomy, which may have contributed to the shock of surgery and fatal result.

It is not the purpose of this paper to cite two isolated cases of traumatic diaphragmatic hernia with acute strangulation of the stomach as therapeutic triumphs. The operation in itself is not unusual nor technically difficult and the importance of considering the subject lies in the recognition of the defect and its surgical correction before strangulation occurs. Once the diagnosis of a traumatic diaphragmatic hernia has been made, surgical repair should be performed even though the patient is entirely free of symptoms. In the quiescent type, reduction of the hernia at operation is usually a simple procedure and the repair of the diaphragmatic opening relatively easy. The statistical evidence of acute strangulation in hernia in this location is extremely difficult to estimate, largely due to the fact that undoubtedly many cases of this type are never diagnosed, probably on account of their lack of symptomatology, and hence are never observed. This would further indicate that it is only the occasional case which goes on to strangulation. In spite of the obviously small percentage of cases which eventually require emergency surgery for a strangulated abdominal viscus, even such a rare occurrence justifies routine repair of all such abnormalities as soon as the diagnosis is established.

tion of the stomach, one is impressed with the few reports concerning this complication. This is evidenced by the fact that there have been but four cases reported in which the stomach has been the strangulated organ. The first case report[2] concerned a 25-year-old psychotic man who stabbed himself in the left side of the chest in 1920. Nothing remarkable occurred then or for the following few years other than a lack of appetite, which was felt due to his psychotic nature. In 1924, four years following the stab wound, the patient first showed signs of complete obstruction as evidenced by vomiting, fever, and general malaise. After a short period of observation the diagnosis of a strangulated stomach and a diaphragmatic hernia was made and a laparotomy was performed. An enormously dilated stomach was found herniated through a small opening in the left diaphragm, and trocar aspiration of the stomach was performed before it could be returned to the abdominal cavity. The patient did poorly immediately following surgery and died on the first postoperative day.

The second case showing definite involvement of the stomach in a hernia of this nature was reported by Wright.[3] This patient was a 52-year-old woman admitted to the hospital with acute epigastric pain of sudden onset four days previously. The history revealed that she had suffered a severe blow to the upper abdominal region nine months before, but had experienced no difficulty since that time. On admission to the hospital she complained of severe pain in the left shoulder, and in order to breathe she had to sit up and lean forward. The diagnosis of intestinal obstruction was made and a laparotomy disclosed the stomach, spleen, and omentum incarcerated in a left diaphragmatic hernia. Reduction was accomplished, and the stomach was purplish, but appeared viable. The hernia was repaired and the patient died two hours following surgery.

The third case, appearing in the Spanish literature,[4] was reviewed by DeBakey. Here the author reported a strangulated diaphragmatic hernia in which the stomach was the only organ involved. Diagnosis was made preoperatively from roentgenograms showing a gaseous circle with a liquid level above the left half of the diaphragm. The onset was sudden two days before admission followed by a few hours of sudden continuous pain in the upper left abdomen and at the base of the left thorax with considerable respiratory distress. Three years before admission the patient had had a repair of the left strangulated diaphragmatic hernia. Left thoracotomy was performed on both occasions and the stomach containing diaphragmatic hernia was reduced with excellent results. This is the only case on record in which both strangulated hernias were successfully treated.

The fourth case report[5] described a 37-year-old man who was admitted to the hospital complaining of severe abdominal pain. Physical findings revealed a left pleural effusion which needle aspiration proved to be bloody in character. Under supportive treatment the patient died in forty-eight hours, and post-mortem examination revealed a left diaphragmatic hernia with strangulation of the stomach and omentum and a large quantity of bloody fluid in the left pleural space. The stomach was gangrenous throughout the upper third. No history of previous chest or upper abdominal injury was

TRAUMATIC CHYLOTHORAX

A Review of the Literature and Report of a Case Treated by Mediastinal Ligation of the Thoracic Duct

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INJURY to the thoracic duct in the chest and the ensuing escape of chyle into the free pleural space constitutes a grave catastrophe in which there is scarcely an even chance of recovery. The seriousness, the rarity, and the fascination of this condition have led to the sporadic reporting of cases by many observers with diverse opinions and speculations concerning the management of the problem. Most of the therapeutic measures have followed the hope that spontaneous closure would occur and have in general been supportive in character. Ligation of the duct in the chest has been mentioned as physiologically feasible but has not been successfully carried out as a part of therapy. The purpose of this paper is to present a case of traumatic chylothorax with recovery following transpleural mediastinal ligation of the thoracic duct.

The thoracic duct is a thin tenuous structure which courses from the cisterna chyli upward along the vertebrae in front of the right intercostal vessels and behind the esophagus to the upper mediastinum where it diverges to the left to pass behind and above the great arteries in the neck to empty into the subclavian vein at its junction with the left jugular vein. Lee,[1] with meticulous care, has demonstrated that there are many small collateral branches which are in conjunction with the main duct and that some of these communicate by small filaments with the lumbar, intercostal, and azygos veins. This anatomic observation has been further substantiated by the experience of surgeons[2-5, 10] who have ligated the thoracic duct in the neck with impunity and by investigators[1, 6, 7] who have occluded it in animals without deleterious effect. The thoracic duct and its tributaries serve as the channel through which chyle is carried from the digestive system to the venous circulation. Histologic study of the duct shows that in its wall there are fibers of smooth muscle[8] and it has been indicated that rhythmic contractions of these fibers help to propel the chyle upward along the duct. The changes in the intrathoracic pressure with respiration and the accumulation of chyle in the cisterna chyli are also most important factors in its flow. Under normal conditions the pressure in the duct is very small but it has been observed that after ligation it can reach 35 cm.[9] of water. The rate of flow and the volume carried are dependent, within a certain range, upon the amount and character of the oral intake of the individual. It has been estimated that the flow of chyle in man varies between .38 and 3.9 c.c.[10] per minute or 60 to 190 c.c.[4] per hour, or approximately 2 liters a day.

From the Surgical Service and the Chest Group of the Hartford Hospital.
Read (by title) at the Twenty-Seventh Annual Meeting of The American Association for Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

SUMMARY AND CONCLUSIONS

1. Two cases of acute strangulation of the stomach and traumatic diaphragmatic hernia occurring in the military service are presented. Successful results were accomplished by prompt transthoracic reduction and repair of the defects.

2. A review of the available literature on the subject is given. Four similar cases have been reported with the mortality of 75 per cent.

3. All traumatic diaphragmatic hernias should be repaired as soon as the diagnosis is made and certainly before signs of obstruction occur.

4. The transthoracic approach is the method of choice in the repair of hernias of this type.

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TABLE I. BACTERIOLOGIC STUDIES WITH CHYLOUS FLUID*

PERCENTAGE OF CHYLE	PERCENTAGE OF PHENOL RED BROTH	REACTION IN 24 HOURS	GAS IN 24 HOURS	PROTEIN CHANGES
		E. Coli W.		
100	0	Alkaline	0	0
50	50	Acid	Plus	Coagulation
30	70	Acid	Plus	Coagulation and digestion
20	80	Acid	Plus	Coagulation and 3+ digestion
0	100	Acid	Plus	Complete digestion
		Staph. 204		
100	0	Alkaline	0	0
50	50	Acid	Plus	Coagulation
30	70	Acid	Plus	Coagulation and digestion
20	80	Acid	Plus	Coagulation and digestion
0	100	Acid	Plus	Complete digestion

*Phenol red broth was diluted with varying amounts of chyle and then used as a culture medium for *E. Coli* W. and Staph. 204. The amount of growth was gauged by change in pH and volume of gas produced. In addition, change in protein content was noted.

Transplants from pure chyle to blood agar plates and endo showed 4 plus growth indicating that pure chyle is bacteriostatic and not bactericidal.

TABLE II. VALUES OF IMPORTANT CONSTITUENTS IN CHYLE AND CORRESPONDING BLOOD LEVELS

DATE 1946	AMOUNT (C.C.) CHYLE	COLOR CHYLE	N-P-N (MG. %)		PROTEIN (GM. %)		SUGAR (MG. %)		CHOLESTEROL (MG. %)		CALCIUM (MG. %)		PHOSPHATE (MG. %)		CHLORIDE (MG. %) CHYLE	SP. GR. CHYLE	PH CHYLE
			CHYLE	BLOOD	CHYLE	SERUM	CHYLE	BLOOD	CHYLE	BLOOD	CHYLE	BLOOD	CHYLE	BLOOD			
2/5	300	Thin, milky															
2/12	1700	Chylous	25	26	3.8	5.8	122	80	97	120	7.5		4.6		660		
2/20	700	Thin, milky														1.017	7.7
2/21	900	Thin, milky			3.7	6.5		93	91			11.5		3.4		1.021	
2/24	1050				3.1		119		94							1.010	
2/28	2100	White, opaque	21		3.0		122		92		7.8		4.1		735		

Chylothorax is by definition the condition which results when chyle accumulates in the free pleural space. This occurs in the presence of serious and frequently fatal disease such as venous obstruction to the superior vena cava, lymphatic block in filariasis, erosion of the duct or its radicals by malignant neoplasm, or tuberculosis.[11] The escape of chyle from trauma, which may be direct or indirect, constitutes the main theme of this paper.

When chylothorax develops following direct laceration which severs the duct as in bullet wounds,[4, 14, 23, 31] surgical accidents[16, 23, 27, 29] and fractures of adjacent vertebrae,[20] or following indirect injury which tears it by concussion, or traction from external blows[15, 18, 30] or even coughing, there is always a latent period before symptoms appear. This interval is usually three to seven days but may be as long as months.[18, 25] The delay is the time required for the chyle to escape from the extrapleural mediastinum into the pleural space and fill it to the point where the volume of fluid embarrasses respiration and causes distress. In some instances, this alteration of respiratory physiology will precipitate cardiovascular collapse and shock which will respond to thoracentesis.[14, 29] In patients in whom the condition has been of long duration, accompanied by frequent thoracenteses, hypoproteinemia, weight loss, and inanition are marked due to failure of essential products of nutrition to enter the circulation.

The diagnosis of chylous effusion is established by the character of the pleural fluid. Chyle is a milky, thin fluid with a specific gravity of 1.010 to 1.021, and alkaline in reaction. It contains lipoid substances which are stained by sudan III. The values for electrolytes, protein, sugar, and cholesterol in chyle approximate those of the serum but are subject to wider variations which may be a direct reflection of the diet.[10] Chyle is a vehicle for the mobilization of proteins which, in the presence of hemorrhage, are redistributed and made available for essential functions.[6] Chyle is bacteriostatic as demonstrated by the low incidence of empyema and by the many sterile cultures after repeated thoracenteses in the reported cases. This has been substantiated in the Hall-Wilson Laboratory of the Hartford Hospital where cultures of *Eschericha coli* and *Staphylococcus aureus* failed to multiply in pure chyle. Table I indicates the results of these observations. Table II records the values for some of the constituents of chyle as well as the corresponding blood levels. It also indicates the date and amount of the various chest taps.

Traumatic chylothorax is an extremely unusual disease, and there are only sixty-nine cases of it recorded in the accessible literature. Shackelford and Fisher[13] in 1938 reported two cases and presented in tabular form a very excellent summary of thirty-nine other cases previously recorded in the literature. Eleven incomplete reports were discarded due to the lack of detailed description. Since their paper, seventeen additional cases have been reported, and they are summarized in Table III, making a grand total of sixty-nine. The therapeutic results for the series of fifty-eight cases which could be analyzed show a gross mortality rate of about 45 per cent and are given in Table IV. The ages ranged from 9 to 62 years; forty-seven were males, and eleven females. This is to be expected in a traumatic disease.

TABLE III—CONT'D

AUTHOR	DATE	AGE AND SEX	NATURE OF TRAUMA	CLINICAL COURSE	SIDE	THERAPY	RESULT	AUTOPSY FINDINGS
7. Matson and Stacy[21]	1940	21 M	Gunshot wound of right chest	Patient in shock, right chest showed pneumohemothorax, tapped repeatedly, on twelfth day chyle first noted	R	Repeated thoracenteses. 22,440 c.c. Gomenol and oil injected. By end of five months patient well.	R	
8. Hoyer[22]	1941	56 M	Hit by auto	Fractures of the ninth, tenth, and eleventh ribs on right; 5 days later chylothorax detected	R	Repeated thoracenteses. 6,600 c.c. total. Discharged well forty days after accident	R	
9. Smith and Woliver[23]	1941	17 F	Surgical accident	Thoracic duct injured and not ligated during resection of a Ewings tumor of the tenth rib and vertebra, third P.O. day dyspnea developed, well fifteenth P.O. day	R	Thoracentesis on fifth P.O. day 900 c.c. In next twelve days 7,800 c.c. removed. 3,000 c.c. given intravenously. Spontaneous closure on fifteenth P.O. day.	R	
10. Dorsey and Morris[24]	1942	60 M	Fell down stairs in alcoholic stupor; fractured tenth rib	Twenty-eight days later developed dyspnea; right thoracentesis, 3,100 c.c. of milky fluid, died 46 days after injury	R	Repeated thoracenteses. 18,400 c.c. removed in eighteen days. 3,500 c.c. given intravenously. Died of inanition.	D	The thoracic duct was injected with India ink and showed a small puncture-like opening in the duct lying over the 12th thoracic vertebra. 9th and 10th ribs fractured. No fracture of the vertebra
11. Little, Harrison, and Blalock[25, 26]	1942	17 F	Auto accident	Seven weeks later dyspnea; 1,500 c.c. chyle from left chest, later right chest and peritonium involved	R & L & A	Repeated taps of chest and abdomen. Intravenous reintroduction of total of 11,100 c.c. of chyle. After eighteen months abdominal chyle still accumulated. Over 500 liters were removed from chest and abdomen. Patient finally died.	D	Patient died outside of hospital. Autopsy not obtained
12. Whitcomb and Scoville[27]	1942	39 F	Surgical accident	Thoracic duct injured and recognized and clipped during right sympathectomy; fourteenth day severe dyspnea, died in anaphylactic shock	R	Repeated thoracenteses. Intravenous chyle was given slowly. After 75 c.c. patient went into anaphylactic shock and died.	D	Permission refused.

TABLE III. SUMMARY OF CASES OF CHYLOTHORAX REPORTED IN THE LITERATURE SINCE 1936[13]

AUTHOR	DATE	AGE AND SEX	NATURE OF TRAUMA	CLINICAL COURSE	SIDE	THERAPY	RE-SULT	AUTOPSY FINDINGS
1. Strauss[14]	1936	24 F	Bullet wound of chest	Ten days later shock and dyspnea, diagnosis chylothorax made by thoracentesis, recovered after 3 mo.	R	Repeated thoracenteses and pneumothorax. 30 aspirations—79,800 c.c. removed	R	
2. Brown[15]	1937	? F	Auto accident with collision	Two months later chylous ascites; laparotomy done, seventeen days P.O. dyspnea with bilateral chylothorax, died 4 mo. after injury	R & L & A	Laparotomy. Repeated thoracenteses. Posterior drainage of mediastinum	D	Interruption in continuity of thoracic duct 2.5 cm. above the diaphragm. Fibrosis about the distal end occluding the lumen. Chylous fluid in both pleural cavities and in the peritoneal cavity
3. Douday, Dupuy, and Bouvrain[16]	1938	30 M	Lysis of adhesions of left lung by thoracoscope for Tbc.	The next day fever and dyspnea appeared and fluid above the diaphragm; tap showed it to be milky	L	Seven days later 100 c.c. of milky fluid removed. Fifteen days later complete recovery from chylothorax	R	
4. Fujita, Bando, and Sugishita[17]	1939	10 M	Struck at play in left infra-clavicular region	Fracture of first left rib and chylothorax developed on left	L	Repeated chest taps. Incision made in left neck and cervical thoracic duct compressed with a pack. Recovered after three months	R	
5. Gordon[18, 19]	1940	31 M	Severe blow on chest while at work	One month later cough, L.M.D. tapped chest and found milky fluid, cough persisted, bed rest, 7 mo. later went to hospital, discharged after 4 mo. requiring aspiration once a month	R	Repeated thoracenteses. 950 to 1500 c.c. removed on frequent occasions for three months. Chest irrigations with azochloramid. Fluid diminished	R	
6. Cellan-Jones, and Murphy[20]	1940	32 M	Severe blow and crush of chest and mid-back while at work	Three days later developed dyspnea and collapse, downhill course; died 15 days after injury	R	Repeated thoracenteses. Twenty-seven pints removed in twelve days	D	At post-mortem ninth and tenth vertebrae were fractured and the thoracic duct torn as well as the parietal pleura communicating with the right chest cavity.

R, Right
L, Left

A, Abdomen
R, Recovered
D, Died

(Table III continued on following pages.)

TABLE IV. SUMMARY OF THERAPEUTIC RESULTS IN FIFTY-EIGHT CASES ANALYZED IN THE LITERATURE

	RECOVERED	DIED	UNKNOWN
Total of fifty-eight cases	31 (53%)	26 (45%)	1 (2%)
Nonoperative therapy	22	19	1
Rib resection	6	4	
Cervical ligation	2		
Phrenic crushing	1	1	
Posterior drainage		1	
Posterior ligation		1	

The most striking feature in the management of these patients is the multitude of ingenious suggestions which have been considered or executed in the treatment. Frequent thoracenteses for the relief of respiratory distress have been almost universally used. Pneumothorax for the purpose of discouraging the flow of chyle has been done without great success. Instillation of sterile broth[28] and irrigations with azochloramid[18] and other substances[21] to stimulate fibrinous reaction have been resorted to with some benefit. The phrenic nerve was crushed twice with doubtful success.[28, 30] The intravenous[13] or intrasternal[29] injection of chyle has been done with benefit, but in one instance in the Hartford Hospital it resulted in sudden death from anaphylactic shock.[27] The intravenous administration of chyle is not safe even though it has been accomplished successfully. Restricted diets low in fluids, fat, and protein have had beneficial results in reducing the production and flow of chyle. Rib resections[12] have been done to establish an external chylous fistula, and also under the mistaken diagnosis of empyema. Surgical drainage of the mediastinum through the posterior approach has been attempted[15] with the thought that a free external flow of inspissated chyle would encourage healing of the rupture in the duct. These methods have been instituted in the hope that spontaneous closure of the mediastinal sinus would occur. Direct injury to the thoracic duct in the neck has resulted in external chylous fistula[10] or in chylothorax.[4, 17] Both of these conditions have been controlled by ligation of the cervical thoracic duct. Retropleural ligation of the thoracic duct for the control of chylothorax resulting from a surgical accident during a bilateral splanchnicectomy has been done without success.[29]

When conservative measures fail, and it becomes clear that spontaneous repair and closure are unlikely, then one is justified in risking a direct attack through the chest at or below the site of the rupture with the intent to ligate the duct low in the mediastinum. The case which is presented in this paper establishes the fact that low ligation of the thoracic duct is a feasible procedure. The chylothorax promptly ceased and the patient has remained free from it for over one year.

CASE REPORT

Mrs. S. S. (Hartford Hospital, No. 530-622), a 35-year-old married machine operator at a soap factory, came to the outpatient department on Jan. 22, 1946, with a chief complaint of shortness of breath. Two months before, while visiting in Maine, she developed a respiratory infection which was thought to have been a mild pneumonia and which was accompanied by very severe paroxysms of coughing productive of a moderate amount of sputum. The patient was confined to bed for one week under medical care but was not hospitalized. Following this acute episode she was never entirely well. A chronic, nonproductive cough

13. Schnug and Ransohoff[28]	1943	23 F	Bullet wound between fifth and sixth ribs	Immediate exploratory laparotomy, 6 days later developed dyspnea, right chest tapped and chyle found; 56,450 c.c. removed by tapping over 33 day period	R	Right phrenic crushing on 15th day. 16,800 c.c. chyle given by vein. 32nd day 50 c.c. of sterile broth injected into chest to stimulate fibrinous closing of tear. Chyle stopped 33rd day.	R	
14. Peet and Campbell[29]	1943	47 M	Surgical accident	Bilateral splanchnicectomy for hypertension, 11 days later chylothorax with sudden cardiovascular collapse and dyspnea	R	Thoracentesis three times in five days. 10,700 c.c. removed. Chyle given intravenously and intrasternally. Ligation of thoracic duct attempted. Patient died suddenly.	D	Post mortem revealed the thoracic duct to be completely interrupted at the level of the eleventh thoracic vertebra. No satisfactory explanation for sudden death was found
15. Florer and Ochsner[30]	1945	14 M	Fell from iron framework	Four days later dyspnea, tap 1,100 c.c.; no fractured ribs or vertebrae found	R	Sixteen taps. 26,000 c.c. removed. Right phrenic crushed. Intravenous chyle given. Fat free diet. Died twenty-four days after injury.	D	Perforated duodenal ulcer. The thoracic duct showed marked narrowing 3 cm. above cysterna chyle. There was a small rent in the pleura at the eleventh intercostal space. No fractures found.
16. Loe[4]	1946	? M	Bullet wound in neck in action on Saipan	Arrived on hospital ship in shock and respiratory distress	L	Taps twice daily to relieve dyspnea. Total of 18,000 c.c. removed in nine days. Fourth day recognized as chyle. Ninth day duct ligated in neck	R	
17. Berry[31]	1947	28 M	Shrapnel wound in left chest in action in Germany	Arrived army hospital in fair condition with respiratory distress; x-ray showed large foreign body in left chest, thoracotomy done, fragment removed from upper posterior chest wall, 48 hr. later developed dyspnea, thoracentesis done; 800 c.c. blood-stained chyle obtained	L	Repeated thoracenteses daily for eight days. Spontaneous cure by fourteenth day. 10,375 c.c. removed in all	R	

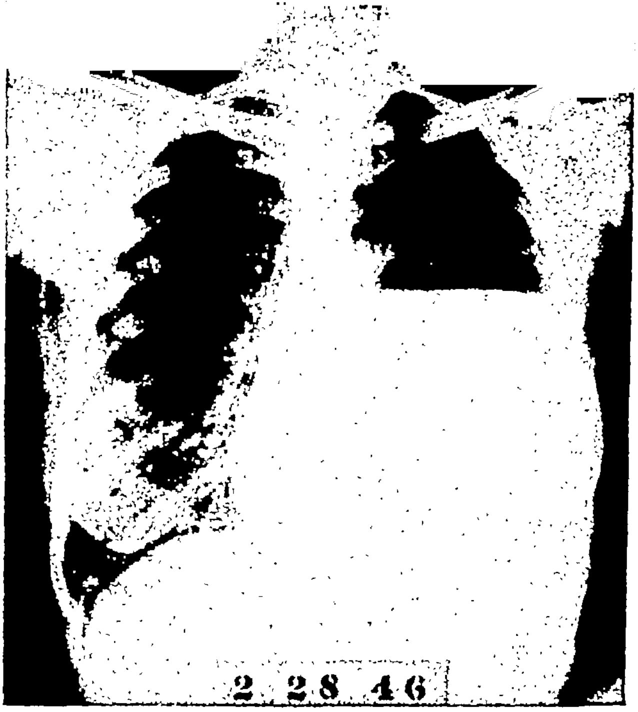

Fig. 2.—Chest roentgenogram taken just before operation showing large collection of chyle in the left chest and pneumothorax.

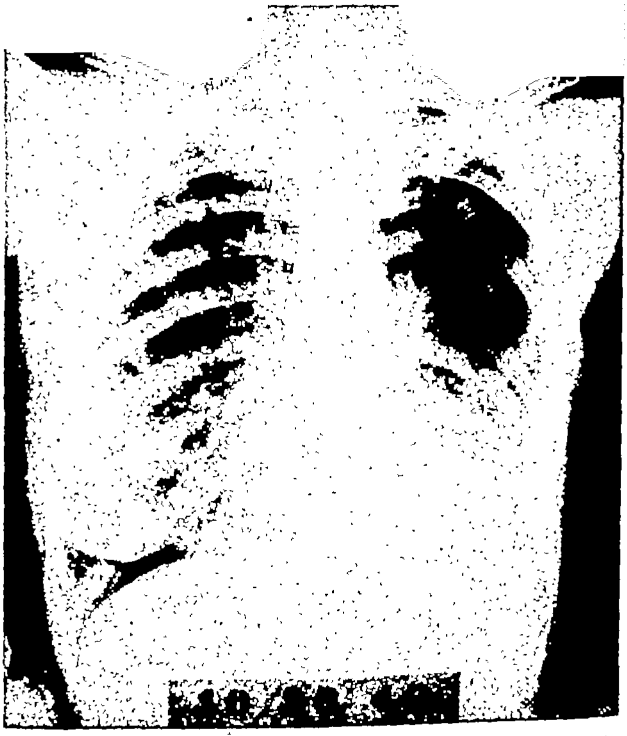

Fig. 3.—Follow-up chest x-ray picture taken eight months after operation showing some residual pleural thickening at the left base.

persisted, and shortness of breath was experienced when walking or climbing stairs. About three weeks before entry to the outpatient department these symptoms quite suddenly became markedly worse, and the patient could not walk because of severe dyspnea from the slightest exertion. She was referred by her doctor to the clinic. During the recent illness she lost ten pounds in weight. Previous general health had been good. The family history was significant in that her mother had died at the age of 29 years of tuberculosis, and her father had died of an unknown cause.

The initial physical examination disclosed the following positive findings: height 5 feet 6 inches, weight 112, temperature 97.8° F., pulse 102, respiration 22, and blood pressure 108/70. Her appearance was that of a thin, white woman in no acute distress and with good color. The chest showed good expansion but very little excursion of the left diaphragm. The pulmonary fields were resonant everywhere except on the left in the lower portion posteriorly and in the axillary line. Breath sounds were diminished in this area. There was an area of egophony immediately below and medial to the left scapula along the spine. No râles or rhonchi were heard.

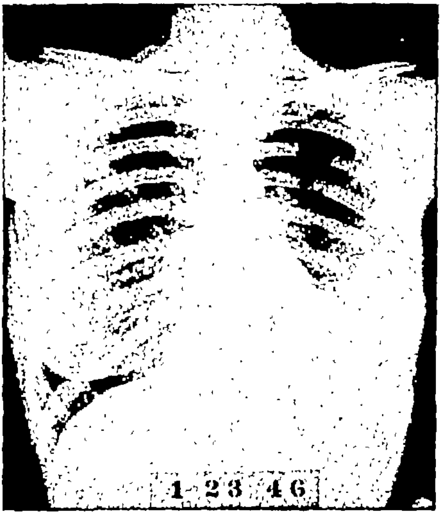

Fig. 1.—Initial chest x-ray view taken in the outpatient department on Jan. 23, 1940, showing fluid at the left base.

The initial laboratory findings were as follows. Urine: acid, specific gravity 1.020, albumin 1 plus, sugar 0, casts 0, cells 0. Blood: hemoglobin 91 per cent, hematocrit 51, basal sedimentation rate 15 mm. per 1 hour, polymorphonuclears 70 per cent, lymph 30 per cent, red blood cells and platelets appeared normal. Serology: Mazzini and Hinton negative. Electrocardiogram was done and was not diagnostic of cardiac abnormalities. X-ray examination of the chest was reported as follows: Films of the thorax showed a moderate amount of pleural fluid or thickening at the left base, the cause for which was not apparent. There was generalized exaggeration of the pulmonary structures throughout both lung fields, and an underlying pulmonary pathologic process could not be excluded from the left base where the pulmonary parenchyma was obscured by fluid.

just anterior to the aorta through which chyle could be seen to appear. The gutter anterior to the aorta was blocked above and below this point with gauze, and it was accurately determined that the chyle originated from this point and did not flow to it from a leak more distantly located. Digital and visual examination of the mediastinum above the heart showed no abnormalities. The phrenic nerve was visualized and there was no interference with it within the chest. The diaphragm also moved with respirations, indicating that there was no paralysis of the phrenic nerve as had been thought by the preoperative fluoroscopic x-ray reports. A four and one-half inch incision was made in the mediastinal pleura just anterior to the aorta and below the inferior pulmonary ligament approximately at the level of the ninth dorsal vertebra. The esophagus was identified and dissected anteriorly. The left vagus nerve was visualized. The aorta was retracted to the left and posteriorly. Directly in front of the vertebral column behind the aorta there was identified a distinct structure the size, consistency, and color of the thoracic duct traveling anterior to the spinal column in the vertical direction. Five grains of methylene blue dissolved in water were injected by the anesthetist through the stomach tube to see if it would appear in the thoracic duct. It did not appear. Two silk ligatures were placed around the thoracic duct and tied. The duct was not divided. The incision in the mediastinal pleura was closed with interrupted silk sutures. A small amount of fibrin foam was inserted to control whatever small amount of bleeding was present. The chest wall was closed in layers without drainage. Following closure, aspiration was done anteriorly with a large needle and about 2,000 c.c. of air were removed. Penicillin, 100,000 units, was inserted through the needle. At the end of the operation the patient was in very good condition.

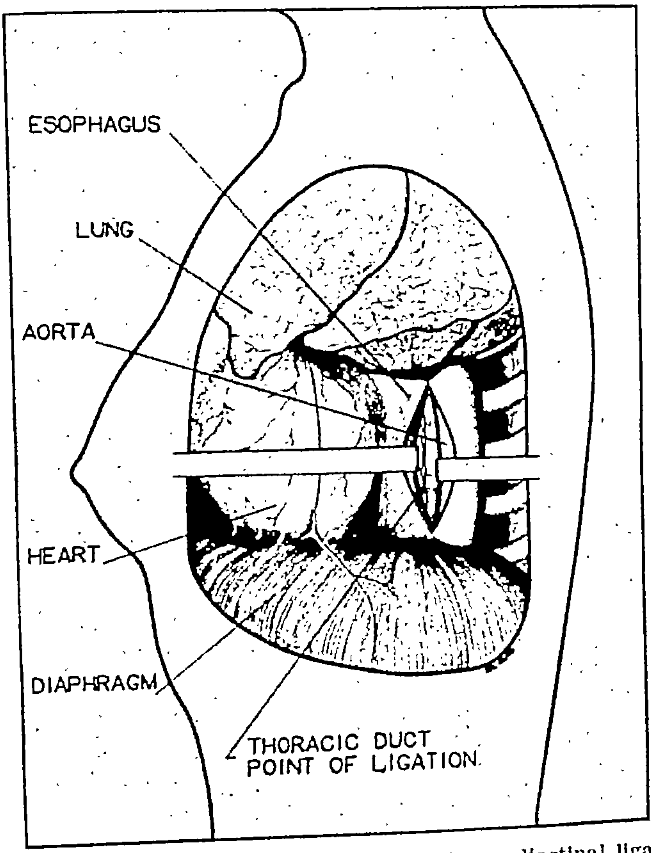

Fig. 5.—Diagrammatic sketch of the operative approach for mediastinal ligation of the thoracic duct.

Two weeks later the patient made a second visit to the outpatient department and a diagnostic thoracentesis was done in the seventh interspace in the left midaxillary line, and 300 c.c. of thin, milky fluid were aspirated. A tentative diagnosis of chylothorax was made and the patient was advised to enter the hospital.

On February 9 the patient entered the hospital for observation, treatment, and study to determine the cause and course of the chylothorax. During the ensuing three weeks five chest taps were done and these indicated that the rate of reaccumulation was increasing. Pneumothorax was instituted in order to give a better radiographic diagnosis of the underlying lung and mediastinum, and in the hope of discouraging the flow of chyle. Neither objective was accomplished. Examination of the chest by fluoroscopy disclosed marked depression of the diaphragm which showed paradoxical motion and gave the impression that the diaphragm was paralyzed. Culture of the chylous pleural fluid produced no bacterial growth and inoculation of chyle with organisms showed that it was bacteriostatic. Repeated sputum examinations failed to show tubercle bacilli. The patient was placed on a low fluid, protein and fat intake which had no noticeable effect in discouraging the reaccumulation of chyle. Intravenous administration of chyle was considered and thought to be inadvisable. Inasmuch as spontaneous improvement failed to occur, it was decided that exploratory thoracotomy with ligation of the thoracic duct below the point of rupture should be attempted. Operation was done on March 1, 1946, and is described as follows.

Fig. 4.—Chyle, 2,000 c.c., removed in one tap the day before operation.

Under endotracheal cyclopropane and ether anesthesia, with the patient lying on the right side, an incision was made over the sixth rib from the anterior axillary line to the posterior end of the rib. The scapula was freed and retracted upward and a subperiosteal resection of the sixth rib was done. The fifth and seventh ribs were divided posteriorly. The pleura was opened and the lung was found to be free except for some thin adhesions posteriorly. The chest cavity contained chylous fluid which was removed with suction. The adhesions of the lung to the posterior chest wall were carefully separated by digital dissection, and the entire left lung was freed. Careful examination along the gutter in front of the aorta finally disclosed a small point adjacent and posterior to the inferior pulmonary ligament side of the aorta. It is not intended that mention of Meade's case should be considered as a report and for this reason it has not been included in the figures of the cases reported in the literature.[32] When the chylothorax occurs in the right chest the approach should be made through a right exploratory thoracotomy and the thoracic duct identified and ligated.[33]

DISCUSSION

The diagnosis of chylothorax in this patient is evident; its etiology is obscure. The history of very severe coughing and the lack of a gross pathologic process in the chest at the time of operation forces the conception that the break in the thoracic duct resulted from the strenuous action of the diaphragm in coughing, which must be considered the traumatic agent. Chylothorax following indirect trauma probably results from the partial rupture of the thoracic duct or one of its radicals. This may not divert the entire chylous flow into the chest. The sequence of events in this case indicates that there must have been an incomplete severance of the duct. The small amounts of chyle in the chest in the initial x-ray, the long latent period, and the slow accumulation of chyle before admission to the hospital all substantiate this impression. Even if one postulates a small perforation of the main duct or the rupture of a small radical, the surgical attack should still be directed at ligation of the main duct rather than at repair of the site of injury, which would be hard to find and even harder to close. It is evident from previous reports and from this case that the chyle is not denied entrance into the blood stream, and that it must make its way through collateral channels to the venous circulation. Even though it has been demonstrated that low ligation of the thoracic duct is feasible, it is a rather difficult procedure and should be reserved for the patient who has demonstrated by the clinical course that spontaneous closure in all probability will not occur.

SUMMARY

1. The literature covering reports of traumatic chylothorax has been reviewed.

2. A case of chylothorax following the trauma of very severe coughing has been presented.

3. Mediastinal ligation of the thoracic duct for chylothorax has been carried out with cure of the chylothorax.

Acknowledgment and appreciation are extended to Dr. John T. Beebe who made the diagnosis, to Dr. Welles A. Standish who assisted at the operation and in the postoperative care, and to Dr. Ralph E. Kendall who directed the laboratory studies.

ADDENDUM

During the second year following the ligation of the thoracic duct, this patient developed severe asthma, and on June 1, 1948, died in the Hartford Hospital of status asthmaticus. Permission for an autopsy was refused. At no time during the two years after operation was there any reaccumulation of chyle in the chest, ascites, or peripheral edema. The patient had always been very thin and remained so. The usual important blood chemistry values on the final hospital admission were essentially normal. The complete picture in this case remains unknown, but the control of the chylothorax was permanent, and the author feels that the patient died of unrecognized pathology and not as a result of the ligation of the thoracic duct.

The immediate postoperative course was uneventful. Chest tap was done on the first postoperative day and 900 c.c. of serosanguineous fluid were withdrawn, which had no suggestion of chyle. Subsequent postoperative taps were done and were entirely free of chyle. The convalescence was slightly complicated by the development of atelectasis of the left lower lobe and the appearance of follicular tonsillitis on the twelfth postoperative day. The patient was discharged from the hospital markedly improved on April 6, five weeks following the operation. At the present time over one year has elapsed and there has been no reaccumulation of the chyle. The patient, however, has had great difficulty in maintaining her weight and there has been some residual fixation of the left chest.

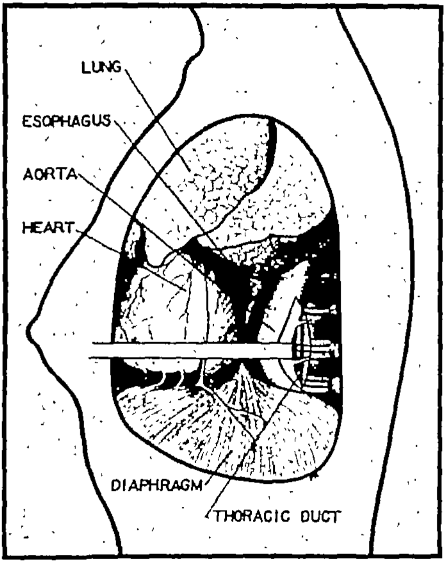

Fig. 6.—Approach used by Meade, with retraction of the aorta forward and to the right.

COMMENT

Since the preparation of this paper, Meade has successfully treated a patient with chylothorax by mediastinal ligation of the thoracic duct through the left chest. In his case the operative approach was made by incising the mediastinal pleura over the aorta and retracting the aorta forward and to the right, exposing the duct between the intercostal arteries and running along the anterior surface of the vertebrae. This approach, according to Meade, is easier than the approach through the left chest by going to the right and in front of the aorta. It is through his kindness that this alternative procedure is illustrated in Fig. 6 so that others who may undertake this operation will be advised that the thoracic duct can be reached through the left chest from the right or the left

COMBINED NITROUS OXIDE, PENTOTHAL SODIUM ANESTHESIA IN THORACIC SURGERY

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WE ARE reporting our experience with this method in 363 consecutive operations at the Detroit Tuberculosis Sanatorium between Jan. 9, 1945, and April 12, 1947. For the most part, these were poor-risk patients for surgical procedures. Two hundred thirty-two operations were on patients with advanced tuberculosis, on whom simpler methods of treatment had failed; 62 others had long-standing infections with accompanying toxemia and possible damage to liver, heart, and kidneys; 30 were carcinomas of the lung, 3 of whom were cyanotic before reaching the operating room. The youngest was 15 years, and the oldest 61 years.

Randolph and Kober[1] had reported favorably on the use of Pentothal sodium in thoracic surgery, chiefly for thoracoplasties. Only 1.7 per cent of their cases showed pulmonary complications.

Paquet[2] also reported very favorably on the use of pentothal for thoracoplasty in a series of 175 operations. He pointed out that with depressed respirations, paradoxical breathing was decreased and that to-and-fro movements of the mediastinum were easily controlled. Hemorrhage was less since pentothal did not cause peripheral vasodilatation. Orton[3] recently reported his use of pentothal for extrapleural thoracic surgery. Moyer and McKittrick[4] found that animals with open pneumothorax anesthetized with pentothal might become permanently apneic following the cessation of painful stimuli. This they attributed to either anoxia or hypercarbia depressing the respiratory centers during the experiment. We have not experienced any similar effect in our series. Heard[5] stated that the only real contraindication to pentothal is the anesthetist's inability to maintain an adequate airway.

Organe and Broad,[6] Ritter,[7] and Shane[8] had recommended the use of nitrous oxide and oxygen with pentothal and stated that this combination greatly reduced the amount of pentothal necessary to maintain anesthesia.

We began our use of this combination on extrapleural cases, and found the results so satisfactory that we quickly extended its use to all cases. Whenever the pleura was to be opened and if there were any question of maintaining an adequate airway the patient was intubated.

Maier[9] has stressed the importance of the closest cooperation between surgeon and anesthetist in thoracic surgery. Not only should the anesthetist maintain a suitable depth of anesthesia, but he must provide an adequate respiratory exchange with a minimum of effort on the part of the patient, even though the mechanism of respiration is materially altered by removal of ribs or the opening

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Read (by title) at the Twenty-seventh Annual Meeting of The American Association of Thoracic Surgery, St. Louis, Mo., May 28, 29, and 30, 1947.

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To prevent undue depression of respiration one must be able to inject small amounts of pentothal and avoid giving large doses inadvertently. Various gadgets have been devised for this purpose, but we have used one designed by our hospital engineer, Mr. C. A. Smith. It consists of a spring holder into which a 20 c.c. Luer-Lok syringe slips easily. Behind the plunger is a gear mechanism operated by turning a small handle at the end of the board upon which it is mounted. One complete turn delivers 4/5 c.c. (5 per cent solution) or 40 mg. This arrangement provides pressure on the plunger at all times and prevents blood from entering the needle and clotting. The board is readily clamped to the table or arm board by a "C" clamp.

In thoracoplasties and other similar procedures in which the pleura is not opened, the patient is placed in position for operation. Usually this is on the side with the lower arm extended on an arm board, the head supported by a small pillow slightly below horizontal; the face is turned toward the table and the table in 10 degrees Trendelenburg. This position allows the tongue to fall forward and provides a free airway.

Two or three minutes after the injection of morphine and atropine, induction is started by giving 4/5 c.c. of 5 per cent pentothal solution (one complete turn of the handle). This is repeated at intervals of 5 to 10 seconds till consciousness is lost. The mask of a McKesson Nargraf machine is then strapped in place and 50 per cent nitrous oxide-oxygen mixture administered by semi-closed technique for four or five minutes; thereafter the closed circle with carbon dioxide absorption is employed. Additional pentothal is added as required to maintain a suitable depth of anesthesia. Artificial airways are not used as they tend to stimulate throat reflexes and induce cough or laryngeal spasm. If the patient is supine the chin must be held up. Occasionally the percentage of nitrous oxide has been increased to 70 per cent during closure.

When the pleura is to be opened the patients are intubated using a woven or metal spiral catheter with an inflatable cuff. A curved catheter connector with suction tube nipple is attached to the end of the catheter to permit ready aspiration of the bronchial tree. At first the method of intubation described by Elliot and Arrowood[10] was followed. This required cocainization of the throat and a prophylactic dose of nembutal one hour or more before coming to the operating room. We have found the use of nembutal delays the recovery from anesthesia. In our last 40 cases we have not used cocainization prior to induction. When the lid reflex is lost, 40 to 80 units of Intocostrin are injected intravenously. The laryngoscope is introduced and the cords visualized. Ten per cent cocaine is sprayed directly on the cords and in 10 or 15 seconds the catheter can be readily introduced. One cubic centimeter of 5 per cent cocaine solution is allowed to run down the lumen of the catheter. This quickly controls any coughing which may occur. Catheters are lubricated with Nupercaine or diothane ointment and are well tolerated even with very light anesthesia. In patients with excess secretions as in bronchiectasis or tuberculosis, bronchoscopy is done after induction and thorough aspiration before intubation.

When the pleura is opened, the lung on that side is allowed to collapse and respirations are aided by slight pressure on the bag during inspiration. The of the thoracic cavity. Many patients will have a lowered vital capacity from pulmonary disease, or such procedures as pneumothorax or phrenic paralysis on the contralateral side. This fact makes it desirable to use an increased oxygen tension during the course of the operation. It is imperative to maintain adequate oxygenation at all times. One must also watch for any evidence of increased CO_2 tension, as this can easily occur even with an adequate supply of O_2. It can be corrected by gentle pressure on the bag during inspiration, thereby increasing the volume of the respiratory exchange.

Nitrous oxide-pentothal anesthesia has several advantages. For the patient it provides a pleasant induction with a minimum of nausea and vomiting in the postoperative period. It permits the surgeon to use an electric cautery and so materially shortens the time of operation. There is no increased bleeding from vasodilatation, as may occur with other anesthetics. For the anesthetist it makes possible a smooth, rapid induction and allows him rapidly to deepen the anesthesia whenever necessary. It permits frequent aspiration of the bronchial tree without fear of lightening the anesthesia or danger from the release of explosive mixture. It avoids excitement during the periods of induction and recovery. Breathing is quiet, somewhat shallow, and only slightly increased in rate; consequently, it is less likely to dislodge purulent material from the diseased portion of the lung. There is little change in blood pressure or heart rate. Recovery is rapid and patients are cooperative as soon as they begin to react.

Pentothal, however, has certain disadvantages. It is a marked respiratory depressant if used too freely. The period of recovery may be prolonged. Throat reflexes remain active and cough, hiccough, and laryngeal spasm are likely to occur, especially if there is any excess secretion in the trachea or nasopharynx.

Coughing must be avoided as it is probably the most important cause of spread in pulmonary disease. Once it occurs it is not readily controlled by deepening the anesthesia. The offending secretions must be aspirated. Cough, however, can usually be avoided by omitting all preoperative medication and encouraging the patient to continue raising the secretions until he arrives at the operating room. We have found this very important. Premedication in the usual doses given one hour before operation will depress the cough reflex and allow secretions to collect which will give trouble during induction and maintenance of the anesthetic.

After the patient is in position on the operating table morphine sulfate, 1/12 to 1/6 gr., with atropine sulfate, 1/300 to 1/150 gr., is given intravenously using an 18 or 20 gauge needle. The hypodermic syringe is then disconnected and the tubing from the pentothal syringe connected. The needle and tubing are securely fastened in place with adhesive. We prefer an 18 or 20 gauge needle as it is seldom occluded by blood and it can be used to give additional fluids should the need arise. In most cases we have used a 5 per cent solution of pentothal. We prefer atropine to scopolamine as we found that patients receiving scopolamine were likely to be delirious and uncooperative during emergence from anesthesia.

TABLE I.

OPERATION	DISEASE	TIME OF DEATH	CAUSE
Thoracoplasty 2nd stage	T.B.	10th P. O. day	Cardiac failure, syphilitic heart disease
Thoracoplasty 2nd stage	T.B.	3rd P. O. day	Diabetic coma, severe diabetic
Thoracoplasty 2nd stage	T.B.	13th P. O. day	Pulmonary hemorrhage
Revision thoracoplasty	T.B.	4th P. O. day	Cardiac failure
Revision thoracoplasty	T.B.	5th P. O. day	Cardiac failure
Sequestrectomy	Osteomyelitis of rib	14th P. O. day	Meningitis
Lobectomy	T.B.	5 weeks	Developed bronchial fistula, 4 weeks P. O.
Lobectomy	Carcinoma	2 days	Pulmonary edema
Lobectomy	T.B.	11 months	Spread and reactivation of opposite side
Pneumonectomy	T.B.	On table	Cardiac arrest following clamping of main stem bronchus
Pneumonectomy	T.B.	8 weeks	Spread
Pneumonectomy	T.B.	4th P. O. day	Cardiac failure
Pneumonectomy	T.B.	9 weeks	Myocardial failure, amyloidosis
Pneumonectomy	Carcinoma	2nd P.O. day	Embolus to brain, hemiplegia
Pneumonectomy	Carcinoma	On table	Hemorrhage from pulmonary artery
Exploratory and biopsy of mediastinal glands	T.B.	36 hr. P. O.	Myocardial failure
Exploratory	Carcinoma of stomach and esophagus	1 day	Massive hematemesis
Exploratory	Carcinoma of lung with bronchial obstruction	3 days	Myocardial failure following attempt to go to lavatory
Excision of secondary carcinoma involving chest wall and segmental resection of lung	Metastatic carcinoma	21 days	Carcinoma, hypernephroma

This was frequently associated with coughing, narcotics, or ingestion of food. Only three patients had severe persistent vomiting. One of these was a severe diabetic, difficult to control.

Patients in whom intubation was done had less difficulty. Slight nausea and vomiting occurred in 12 per cent of cases. Two had moderate abdominal distention.

Two patients required catheterization postoperatively.

One patient was irrational for two days following one stage of thoracoplasty. Four patients with inoperable carcinoma of the lung who were slightly irrational at times before operation became quite disoriented after operation. These cases can probably be explained on the basis of hypoxia; they came to operation cyanotic, with a bronchus more or less obstructed by the tumor. This prevented a normal exchange of gases in the blood reaching the involved lung. Postoperative elevation of temperature with its increased metabolism might well account for the increase in this symptom. Definite improvement in cyanosis occurs when it is possible to remove the involved lobes. One patient with pneumonectomy became irrational whenever the bladder was distended.

lung is always re-expanded before closure of the chest. If excessive to-and-fro movements of the mediastinum should occur they can be quickly controlled by giving 100 to 150 mg. of pentothal rapidly and deliberately depressing respiration. Adequate exchange is easily maintained by gentle pressure on the bag. There is very little disturbance of blood pressure if blood loss is compensated by blood transfusion. Pulse rate tends to increase 10 to 20 per minute and respirations are usually between 20 and 24, but somewhat shallower than normal.

Five patients received pentothal solution into tissues through the needle tearing a vein or becoming dislodged. These were treated by immediately injecting 2 c.c. of a 1 per cent solution into the area and very little discomfort was afterward experienced by the patient. One patient developed a mild phlebitis at the site of injection. In this case we had chosen a vein which had been used several times for intravenous fluids. We experienced no difficulty with laryngeal spasm. A rather slow induction, adequate oxygen, and attention to expectoration of excess secretions preoperatively lessens the incidence of this complication. Upon return to their rooms most patients receive 1000 c.c. 5 per cent glucose intravenously and 5 to 6 liters of oxygen per minute through a nasal catheter. Six, whose breathing was shallow, were given 3 to 4 c.c. metrazol intravenously with satisfactory results. Usually a patient with secretions will expectorate on command 10 to 15 minutes before fully regaining consciousness.

Patients anesthetized less than one hour receive from 0.3 to 1 Gm. of pentothal and are usually reacting by the time they are returned to their rooms. Patients with pneumonectomies and lobectomies seldom receive more than 1.5 Gm. These patients usually react within one-half hour.

The older patients as a rule take longer to regain consciousness and their blood pressure and pulse changes are somewhat greater.

A tabulation of all deaths, whether from surgery or extension of existing disease, is given in Table I. In no instance do we feel that the anesthetic was a major contributing factor.

Complications were as follows: Thoracoplasties where fair-sized cavities were being collapsed had increased cough for a few days postoperatively. One patient had tracheitis for two weeks following intubation. No cases of atelectasis were diagnosed. All patients who had prolonged postoperative fever were x-rayed. There were four cases of spread, one following pneumonectomy on a very poor-risk patient who died eight weeks postoperatively; one following lobectomy for tuberculosis with death eleven months postoperatively. Two patients with thoracoplasty had evidence of spread which cleared in a few weeks. There was one case of extension of tuberculosis to the right upper lobe following a right lower lobectomy for cavity. This cleared within six weeks.

Gastrointestinal complications were chiefly nausea and vomiting. Thirty per cent of the patients in whom intubation was not done had slight nausea and vomited once the evening of operation, usually after taking fluids. Ten per cent had moderately severe nausea and vomiting for twenty-four to forty-eight hours.

SUMMARY

We are reporting the use of combined pentothal sodium and nitrous oxide in 363 consecutive cases. From this experience we have arrived at the following conclusions:

1. It provides a high oxygen tension.
2. It is nonexplosive.
3. It is nonirritant to the lungs.
4. It has very little effect on blood pressure or pulse rate.
5. Excitement during induction and recovery is avoided. Respiratory depression, cough, and laryngeal spasm can be minimized and the period of recovery need not be excessively long. Postoperative complications have been few, considering the seriousness of the operations and the physical status of the patients.

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TABLE II

NO.	OPERATION	DISEASE	AGE	GM. OF PENTOTHAL	TIME OF OPERATION (MIN.)	TIME OF RECOVERY (MIN.)	AVERAGE B.P. CHANGE	AVERAGE PULSE CHANGE	RESPIRATORY CHANGE
181	Thoracoplasty 83 patients	Tuberculosis	17-60	.350 to 1.6 (Av. .7)	30-120	5-60 (Av. 20)	–5	+15	+4
24	Thoracotomy	Empyema	22-55	.4 to 1.7 (Av. .7)	15-90	5-60 (Av. 15)	–5	+10	+4
15	Cavernostomy	Tuberculosis	27-38	.5 to 1.5 (Av. .7)	25-75	10-60 (Av. 25)	–5	+10	+4
6	Revision thoracoplasty	Tuberculosis	25-30	.4 to 1.2 (Av. .8)	60-145	10-60 (Av. 25)	–15	+20	+2
7	Extrapleural pneumonolysis	Tuberculosis	18-45	.7 to 1 (Av. .8)	50-75	10-45 (Av. 20)	–5	+15	+4
3	Excision of sequestra	Osteomyelitis of ribs	39-60	.7 to 1.1	20-45	5-30	–5	+10	+5
5	Excision of tumors of chest wall	2 benign, 2 secondary carcinoma, 1 osteochondroma	37-54	.35 to .65	20-75	10-30	0	0	0
4	Partial scapulectomy; post-thoracoplasty	Tuberculosis	23-30	.8 to 1	30-45	10	–10	+20	+4
4	Excision of diverticulum of esophagus,	Diverticulum	55-61	.35 to .75	40-70	10	–10	+20	+4
2	Excision of cervical glands	Carcinoma	51-63	.5 to .8	60-100	30	–15	0	0
35	Lobectomies	26 bronchiectasis, 4 tuberculosis, 1 carcinoma, 3 empyema with abscess, 1 hemoptysis	15-52 21-55 55 35	.7 to 1.7	65-150	15-80 (Av. 35)	–5	+6	+4
2	Laryngofissures	Carcinoma	39, 50	1 to 1.2	40-50	30	0	+25	+4
21	Pneumonectomies	1 benign tumor, 13 carcinoma, 7 tuberculosis	40 41-60 16-40	1 to 2.3	150-300	15-75 (Av. 40)	–10	+10	+2
19	Exploratory thoracotomy	17 carcinoma, 2 tuberculosis	39-61 57	.7 to 1.65	110-200	15-75 (Av. 30)	–15	+10	+2
2	Repair of diaphragmatic hernia	Diaphragmatic hernia	42, 45	1 to 1.4	135	40-90	0	+6	0
43	Miscellaneous								

Since more blood circulated through the remaining lung, the authors expressed the view that the functional diffusing surface was either increased in area by increase in the number of capillaries, or increased in efficiency by more blood passing through previously existing capillaries. The efficiency of gas exchange between capillaries and alveoli was, therefore, believed to be increased. The breathing reserves were found to be lower in various degrees of activity. However, even in the most exhausting exercise, the reserves were not completely expended. It was suggested that overdistention of the lung following pneumonectomy is not desrable and that planned procedures to eliminate the possibility of marked mediastinal displacement should be considered.

Studies in adults in the immediate postoperative period have been carried out by Maier and Cournand.[5] Determinations of arterial oxygen saturation demonstrated the unreliability of clinical criteria of anoxia. They found that the majority of patients had slight reduction in arterial oxygen saturation during the first postoperative week after pneumonectomy. In two cases of prolonged arterial oxygen unsaturation, there was a mediastinal shift. The return of the mediastinum to the midline accomplished by aspiration of fluid produced a rapid return of the normal oxygen saturation level.

Cournand and Berry[6] investigated adults at a later period after pneumonectomy and found that the chief difference from normal function was "A reduction in breathing reserve in various states of activity. This reduction, caused by a decrease in maximum breathing capacity, was greater in the older patients because of the cumulative effect of abnormal hyperventilation."[6] They also found that "The decrease in maximum breathing capacity was not proportional to the loss of lung volume and was greatly influenced by the state of distention of the remaining lung. The late effects of pneumonectomy upon gas exchange in the lungs, the state of the respiratory gases in the arterial blood, and the cardiocirculatory function, were insignificant."[6] Furthermore, in four patients on whom a supplemental thoracoplasty was performed, the ventilatory function was not adversely affected. In fact, this procedure definitely helped several of these patients. The authors suggested that emphysema does not, perhaps, in itself prevent satisfactory functional results if the remaining lung is not permitted to expand further after operation. They found a greater incidence of dyspnea in the age group 53 to 65, because of the larger reduction in the ability of the chest bellows to circulate air and the larger ventilating requirements during and following moderate exercise. There was also found a reduction in the efficiency of this group to supply oxygen to the tissues during and immediately following exercise.

In Rienhoff's study[7] of twelve patients who had undergone pneumonectomy, "There has been some difference in the degree of compensatory dilatation in the eight patients with total pneumonectomy who survived operation, but in all of them some hyperdistention occurred. This difference in degree seemed not to depend on the age of the patient." He found a marked tracheal displacement in all his cases and concluded that "We have been able to elicit no evidence whatsoever that compensatory dilatation of the lung in either man or animal is harmful."

AN ANGIOGRAPHIC STUDY OF THE FORM AND FUNCTION OF THE REMAINING LUNG AFTER PNEUMONECTOMY

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BOTH the form and function of the remaining lung after pneumonectomy have become matters of clinical as well as theoretical interest because of the rapid increase in the number of total pneumonectomies being performed. A survey of the experimental and clinical studies which have been made may begin with reference to the comprehensive work on dogs of Longacre, Carter, and associates.[1, 2] They demonstrated that the age of the animals at the time of *pneumonectomy influenced the subsequent behavior of these animals and* also the pathologic findings in the remaining lung. In puppies, the functional capacity of these animals under conditions of physical stress soon returned to normal. There was enlargement of the remaining lung, and, microscopically, increase in number and decrease in size of the alveoli. When adult dogs were used, the functional capacity was found to be greatly reduced after operation. The remaining lung was enlarged but there was evidence of emphysema microscopically. When growing dogs were used, there occurred an early return to normal function to be followed some years later by moderate functional reduction. Microscopic study revealed both regenerative and emphysematous processes. These observations are consistent with those of Bremer,[3] who noted that simple distention by dilation of the alveoli and respiratory units occurred after lobectomy or pneumonectomy in cats. However, a true regeneration by means of new growth of normal alveoli and respiratory units may occur. "Regeneration occurs in the young, dilatation in those whose lungs have ceased growing."[3]

Changes in the remaining lung after pneumonectomy in childhood have been described by Lester, Cournand, and Riley,[4] who measured lung volumes, maximum breathing capacity, ventilation, breathing reserve, and respiratory gas exchange under basal conditions, during moderate and severe exercise, and shortly following exercise. Fifteen normal children and three children who had undergone pneumonectomy were used for this study. The results demonstrated that the total capacities of the remaining lungs were smaller in the three who had undergone pneumonectomy than the total capacities of both lungs of normal children, but larger than that of the right lung alone. The vital capacities in each were greater than the assumed vital capacity of the right lung of controls. The functional residual air was found to be smaller in amount in cases where the lung was not pulled into the opposite chest. The dead space in the bronchial tree was reduced and a relatively larger proportion of the tidal air became effective, provided the total volume of tidal air was not reduced.

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CHART I.

NAME	AGE	DIAGNOSIS	SIDE OF PNEUMONECTOMY	INTERVAL AFTER PNEUMONECTOMY	MEDIASTINAL SHIFT
J. D.	60	Squamous cell carcinoma	Right	6 mo.	Moderate
J. E.	60	Squamous cell carcinoma	Left	8 mo.	None
J. Q.	60	Squamous cell carcinoma	Left	8 mo.	Moderate
I. W.	62	Squamous cell carcinoma	Right	10 mo.	None (thoracoplasty)
A. B.	47	Cylindroma	Right	1½ yr.	None (thoracoplasty)
A. F.	55	Squamous cell carcinoma	Right	2 yr.	Slight
A. B.	63	Squamous cell carcinoma	Right	2 yr.	Marked
J. W.	58	Squamous cell carcinoma	Right	2½ yr.	None (thoracoplasty)
L. R.	48	Mucous cell carcinoma	Right	3 yr.	Moderate
E. S.	18	Adenoma with invasion of lymph nodes	Right	4 yr.	Slight
R. K.	58	Squamous cell carcinoma	Left	7 yr.	Moderate
A. C.	50	Sarcoma	Left	10 yr.	Moderate

As far as any gross alteration of vascular pattern in the remaining lung is concerned, it was seen that there was a notable uniformity of findings among almost all the patients. The vascular pattern presented an essentially normal arrangement, in regard to size of vessels and their distribution. There were some minor abnormalities, and these consisted of:

1. Varying degrees of displacement of the pulmonary artery toward the operated side, accompanying the mediastinum
2. Some angulation and a turning on itself of the uppermost medial branch of the remaining pulmonary artery
3. Visibility of the vessels at a lower level than usual in the lower lobe, delineating a downward displacement of the diaphragm.

These features are well illustrated in Fig. 1: This was a 47-year-old woman who had had a right pneumonectomy three years previously for diffuse mucous-cell carcinoma. Her postoperative course was uneventful and she has remained asymptomatic since operation, complaining of shortness of breath only when performing strenuous activity. Her angiogram revealed a moderate shift of the mediastinum toward the operated side, and demonstrated clearly how the uppermost branch of the remaining pulmonary artery may become "turned on itself" to supply that portion of the lung which has "bulged" into the right side of the chest. This vascular distortion, although present in all cases to some degree, was marked in this patient. It can also be seen in Fig. 1 that the vessels in the lower lobe and the pulmonary parenchyma itself are prominent at a lower level than usual, associated with descent of the diaphragm. The vessels can be seen behind the gastric "air bubble." Aside from these changes, the vascular pattern is within the normal range.

A few observations may be made on the foregoing outline of the work which has been done on the subject. First, there is as yet no evidence in children of changes in the lung as noted in experiments on young animals. Second, some measure of dilatation of blood vessels and hyperdistention of the lung (emphysema?) is believed to occur with mediastinal displacement, which, according to one set of observations, results in interference with function and, according to another, does not. Third, almost all agree that a pronounced deviation of the mediastinum is the factor which produces compensatory changes in blood vessels and parenchyma and resultant reduction in function, particularly in the older age group. For this reason thoracoplasty is advocated by some, either immediately, to obviate mediastinal displacement, or subsequently, in order to improve existing dyspnea.

Since the important question of alteration in form and function is concerned with the ultimate and not the immediate, and since the severest test would be in the older age group, we chose a substantial number of patients with pneumonectomy performed for cancer for clinical study. The time which had elapsed since operation ranged from six months to ten years. According to clinical tests (vital capacity and dyspnea on mild exertion) significantly reduced pulmonary function was not seen, regardless of deviation of the mediastinum, which was not infrequent and was, at times, pronounced. There were a few exceptions in which the remaining lung was known to have been diseased before operation, or in which it became infected, with the sequelae of infection occurring.

It was then evident that a study of the topography of the pulmonary vessels in these cases would throw additional light on the question of the change in form and perhaps offer indirect evidence as to changes in function. Twelve patients ranging in age from 18 to 62 years, who had undergone pneumonectomy for malignant tumors, were utilized for angiographic studies. They were chosen at random, some with and some without pronounced mediastinal distortion, and they represented varying intervals after pneumonectomy, ranging from six months to ten years. (Chart 1.)

The technique of angiography was that developed by Sussman[8] at the Mount Sinai Hospital. The patient received an intravenous injection of 50 c.c. of 70 per cent Diodrast, and five films were taken in rapid succession by a specially devised casette shifter, so that the various mediastinal and pulmonary vessels were successively visualized. There were no serious untoward reactions even among patients over 60 years of age.

The films were studied with the following questions in mind:

1. Are there any gross alterations in size, shape, or distribution of the vascular pattern in the remaining lung?
2. Are there any significant changes in the mediastinum or its vessels?
3. To what extent does the remaining lung expand, as evidenced by the distribution of blood vessels?
4. Is the time element after pneumonectomy itself responsible for significant vascular changes?
5. What happens to the stump of the severed pulmonary artery?

seen two years after pneumonectomy for carcinoma. The postoperative course was essentially uneventful, but he developed the most severe mediastinal shift of all the cases in this series. Even with this marked change in position, there is no significant obstructive element or irregularity in the lumina of the affected vessels, and the pattern of the pulmonary artery and branches in the remaining lung is essentially normal. Hence, no disturbance in cardiopulmonary function need be anticipated from the films, and none, in fact, exists clinically.

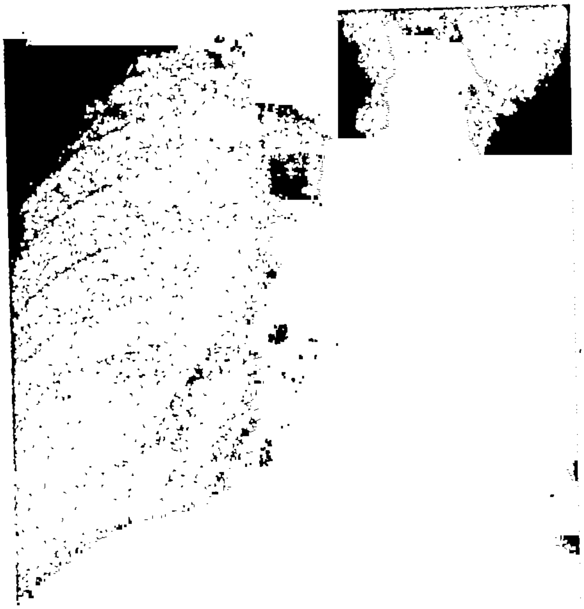

Fig. 2.—Seven years after pneumonectomy. Pulmonary vascular pattern essentially normal except for probable enlargement of main pulmonary artery.

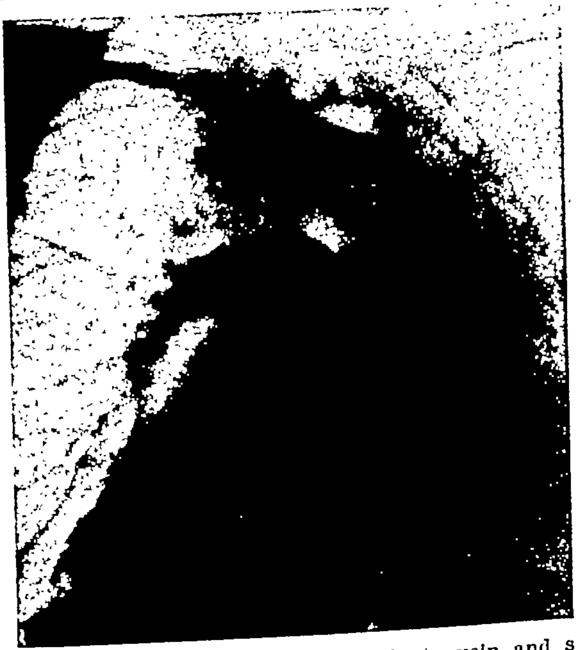

Fig. 3.—Two years after pneumonectomy. Left innominate vein and superior vena cava extremely displaced without symptomatic effect. Normal vascular pattern in remaining lung.

In only one patient did the remaining pulmonary artery appear to be somewhat larger than normal. This was in a 58-year-old patient who was operated upon seven years previously. Even in this patient one cannot be sure of enlargement of the vessel. In the one case in which angiograms were performed before pneumonectomy, there was no significant change in the size of the remaining pulmonary artery when the first angiograms were compared with ones taken six months after operation.

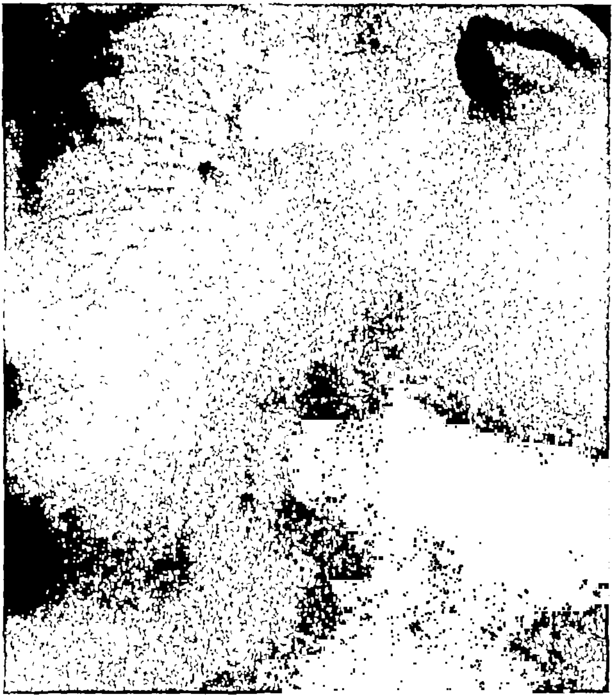

Fig. 1.—Three years after pneumonectomy. Mediastinum moderately shifted toward operated side. Curved superior branch of left pulmonary artery with branches crossing midline, indicates expansion of upper lobe into dead space. Downward expansion of lower lobe visible.

Concerning the major mediastinal vessels, it can be anticipated from Fig. 1, that with this moderate mediastinal displacement, there is no significant displacement of the aorta. This was found to be true in the vast majority of cases. However, the large venous trunks are distorted in some cases, as seen in Fig. 3, in which there is to be seen pronounced displacement of the left innominate vein and superior vena cava. This patient was a 63-year-old man, normal lung and that large areas in the lower lobes function only to a minimal extent except on violent exertion. Thus, the enlargement of the lung after pneumonectomy may represent nothing more than an unfolding or opening up, so to speak, of these areas. The angiograms appear to establish this point for the branches of the pulmonary artery are spread over a larger area, particularly in the lower lobes, but they are unaltered in diameter. Any significant degree of emphysema would probably produce changes in the vascular pattern, according to the classic work of Robb and Steinberg.[9] They demonstrated by angiography that in emphysema, the main branches of the pulmonary artery appear enlarged and the peripheral branches narrowed and wirelike.

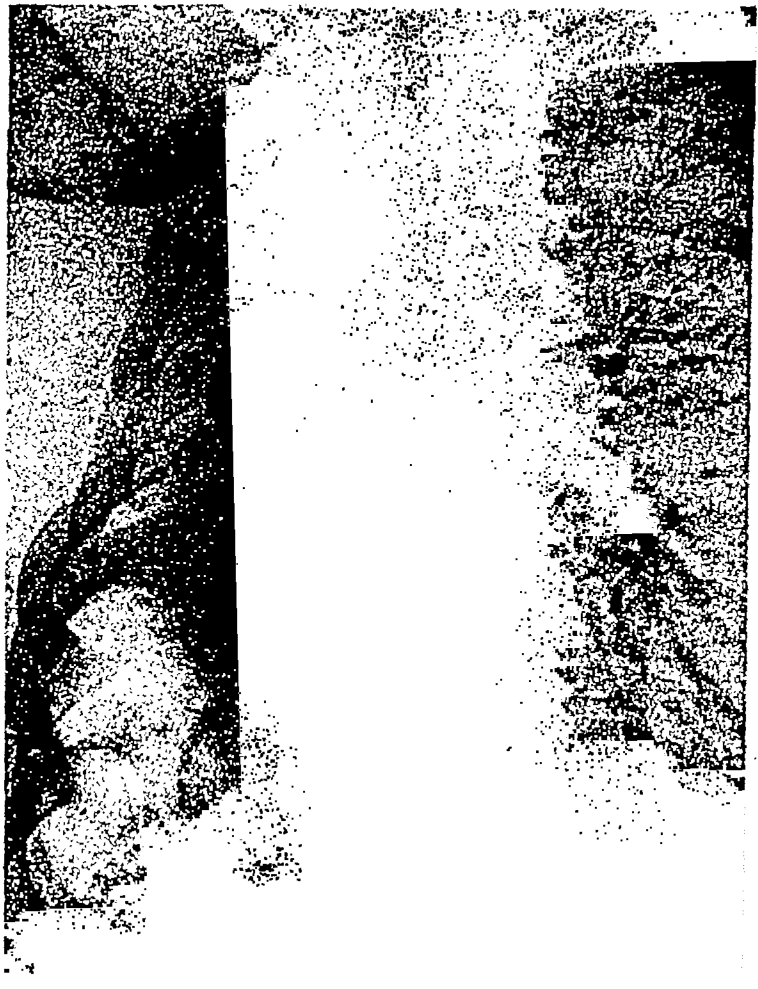

Fig. 5.—Ten years after pneumonectomy. Patient asymptomatic despite displacement of heart and great vessels. Normal vascular pattern in remaining lung.

Concerning changes in the vascular pattern in relationship to the age of the patient and the interval of time since pneumonectomy, the youngest patient in this series was 14 years old at the time of pneumonectomy. The angiograms four years postoperatively revealed the vessels in the remaining lung to be as completely normal as in the older age groups. It was felt that perhaps if a long enough period elapsed after pneumonectomy, there might develop gross

Turning to a consideration of the remaining lung, in this group of cases it is evident from the angiograms that extreme hyperdistention has not occurred even with pronounced distortion of the mediastinum. A portion of the upper lobe "bulges" into the operative area along with the tracheal shift, when mediastinal displacement occurs, as seen in Fig. 1. Judging from the pulmonary vessels within the bulge, the amount of pulmonary tissue involved is not great. In any event the vessels within the bulge are not greatly distorted or angulated and are neither thinned nor widely separated as would be anticipated if pulmonary emphysema occurred in this area.

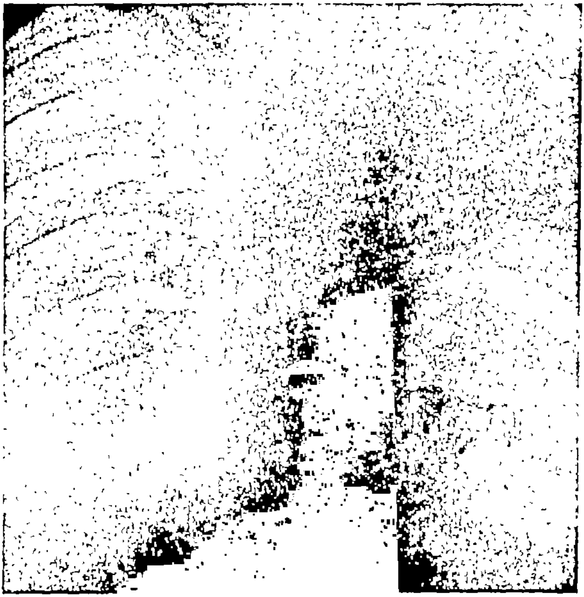

Fig. 4.—Eight months after pneumonectomy. Posterior-anterior erect film. Elevation of diaphragm demonstrates largely obliterated dead space.

A consistent feature is the downward displacement of the diaphragm which appears to be due to an expansion of the lower lobe rather than the lung as a whole, to judge from angiograms. Often enough it is only in this direction that the lung can expand, for the dead space on the operated side may become rapidly reduced by the presence of fluid and the upward shift of the diaphragm (Fig. 4).

The important question is whether or not the expansion of the lung in any direction occurs at the expense of function (emphysema) with "compensatory" changes in the vascular pattern and (or) parenchyma. The angiograms appear to establish that simple expansion occurs. In this connection it may not be amiss to emphasize the proved existence of a considerable reserve in the respiration, the position of the diaphragm, and the physique of the patient are factors which must be considered in the analysis of the films and which render unsafe the interpretation of changes, if any, in the finer branches of the pulmonary artery.

CONCLUSIONS

1. There is no significant abnormality in size, shape, or distribution, of the vascular pattern in the remaining lung after pneumonectomy, in the majority of cases.

2. In this series, when no thoracoplasty had been performed, there often occurred moderate displacement of the mediastinum and great vessels; this was marked in only one case.

3. The expansion of the remaining lung, as judged by the vascular pattern, was not as great in these cases as has been described.

4. There occurs no alteration in size or recognizeable thrombosis within the stump of the resected pulmonary artery.

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vascular changes. In Fig. 5, which is an angiogram performed ten years after pneumonectomy for primary sarcoma of the lung, when the patient was 40 years old, the pulmonary vascular pattern appears to be normal. In this connection it should be mentioned again that in the one patient in this series who did seem to have a somewhat enlarged pulmonary artery, the time interval after pneumonectomy was seven years.

The condition of the stump of the severed pulmonary artery can be considered briefly. In many cases it was clearly visualized and in no instance was there any enlargement or suggestion of thrombus formation. In Fig. 6, which is an angiogram two years postpneumonectomy in a 55-year-old patient, the stump is well visualized. The clips on the adjacent main bronchus are seen, a technique for closure of the bronchus which was employed occasionally at that period.

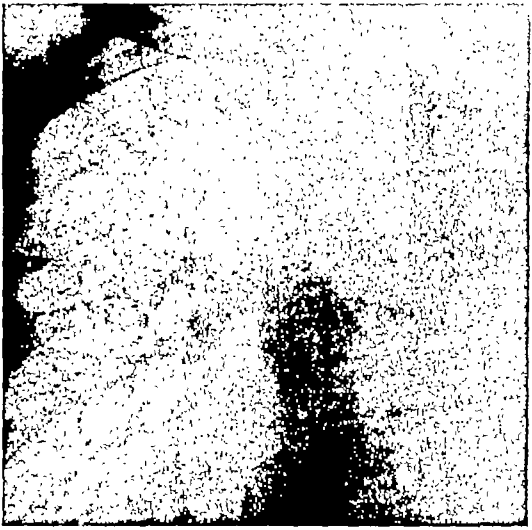

Fig. 6.—Two years after pneumonectomy. Smooth stump of pulmonary artery to be noted below metal clips on bronchial stump. Vascular pattern normal.

A brief discussion concerning the interpretation of angiograms is in order before stating the conclusions which have been reached from this study. In the first place, this appears to be the first investigation by angiography of the remaining lung, and the number of cases is not large. Second, the interpretation of topography by angiograms is direct but the interpretation of function is inferential. Finally, vascular alterations in the finer branches of the pulmonary artery may be present but cannot be safely interpreted by the angiographic technique which has been employed. The position of the patient, the phase of normalities; however, it is not understood why this deviation from normal has taken place or precisely what physiologic or physical aberrations have occurred in the embryo to produce the pathologic state in the infant.

Several hypotheses have been offered to explain the occurrence of cystic tumors of the mediastinum. Lewis and Thyng[15] have noted that knoblike intestinal diverticula are found frequently in embryos of the pig, rabbit, and man. They believe that from these structures there may arise diverticula which usually degenerate and disappear but which occasionally may persist as permanent diverticula or cysts. This observation would, in part, explain the common occurrence of multiple cysts randomly situated along the gastrointestinal tract and the histologic similarity of mediastinal cysts and intestinal reduplications and cysts found by Ladd and Gross[12] and by Poncher and Milles.[22] The latter authors have described the post-mortem findings in an infant 29 months of age in whom there were found an intramesenteric diverticulum arising from the ileum and containing in its wall gastric mucosa and a polyp composed of gastric mucosa and two extrapleural cysts of the mediastinum which contained gastric mucosa, most of which had undergone pressure atrophy and perhaps digestive necrosis.

The findings of Lewis and Thyng perhaps would explain the origin of the mediastinal cyst in the case reported by Steele and Schmitz.[29] In their patient a cystic tumor was removed from the posterior mediastinum and a firm nodule measuring 2 by 1 cm. was found at the lower pole. The nodule was covered by mucosa which resembled that of the fundus of the stomach.

Nevertheless, it is necessary to go beyond this hypothesis to explain the cystic tumors of the mediastinum which are almost complete anatomic and physiologic reduplications of the normal stomach. In such cases there develops within the mediastinum what is virtually an accessory stomach containing mucosa, submucosa, and muscular layers entirely similar to those of the normal stomach and carrying out a functional activity that has in some resulted in peptic ulceration of the wall of the tumor. Such cysts are found only in infants since gastric juices are produced rapidly and retained in a closed space so that the increasing size of the cyst soon causes death by interference with respiratory function, or by rupture into a neighboring organ.

Needham[18] has reviewed the knowledge and theories of functional development of the embryo. From this review one gathers that there is an organizer-hormone (an evocator) present throughout the egg. The organizer is believed to determine the eventual form of cells which it influences. Moreover, the organizer will influence similar cells in a different manner according to their locations.

Schwartz and Williams[25] have utilized the material gathered by Needham in his general review of the subject and have synthesized a theory to explain the development of gastric cysts within the mediastinum. They suggest that gastric cysts develop by this mechanism: "The organiser substance that causes the evagination of the lung buds and their further proliferation, either through some change in time or intensity factors along its gradient causes the evagination of what would form an accessory lung (Nebenlungen) in the region of the cardia of the stomach or lower esophagus. Because of the anatomic situation

GASTRIC CYST OF THE MEDIASTINUM

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ALTHOUGH gastric cysts of the mediastinum are of infrequent occurrence, the serious effects produced by them warrant consideration of the knowledge gained by study of even single cases.

Excellent reviews of reported cases have been made by Olken,[21] by Olenik and Tandatnick,[20] and by Schwartz and Williams.[25] There are, in addition, several cases that have not been included in the reviews of these authors. An appropriate perspective may be gained by a summary of the cases reported to date. Twenty-seven cases[1-33] have been reported and usually no one person's experience has embraced more than a single case. Of the twenty-seven reported cases only two were found in individuals over 15 years of age; nineteen were in infants under 1 year of age; four were between 12 and 24 months of age; and one child was 4 years old. Fourteen were males, ten females, and in three the sex was not stated. From these figures it is apparent that the anomaly is indeed an unusual one and that it is usually of clinical significance in the first year of life.

Terminologic idiosyncrasies and inaccuracies have caused considerable confusion. Cysts containing gastric mucosa have been called gastric cysts, gastrogenic cysts, accessory stomach, mediastinal cysts of gastric origin, thoracic gastric cysts, esophageal duplications, mediastinal cysts of enteric origin, and gastroenteric cysts. In our opinion simplicity and accuracy are served equally well by calling these structures gastric cysts of the mediastinum since it is the gastric mucosa which produces a course different from other mediastinal cysts. That they are cysts containing fluid is without doubt. It is equally true that all contain some elements of the gastric wall; mucosa only in some, all three layers in others. In some the gastric origin of the cyst is recognizable only by a small fragment of mucosa resembling that of the normal stomach. In others the cyst in its entirety may be a facsimile of the normal stomach. This is true in our own case and in the cases reported by several others.[10, 17, 23, 33]

So little mucosa may be present that its secretory nature is not apparent or the mucosa may secrete copious quantities of gastric juice containing hydrochloric acid, pepsin, and rennin.

In infants and children gastric cysts, if at all productive of symptoms, are usually rather rapidly lethal unless they are removed. In adults the difficulties of differential diagnosis among benign cysts of the mediastinum and malignant or potentially malignant tumors are so great that excision is usually desirable and advisable.

THEORIES OF DEVELOPMENT

The entire problem of congenital defects and abnormalities remains considerably shrouded in obscurity despite several explanations that have been offered. It is possible to understand what has happened to produce these ab-

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dyspnea is markedly increased during feeding and that swallowing may produce transient cyanosis. The result will be a serious interference with nutrition and a refusal to eat when deglution interferes with breathing.

Cyanosis, either transient during feeding, crying, and straining, or persistent, follows increased impairment of respiratory function that may be caused by increase in the size of the cyst or by concomitant atelectasis or pneumonia.

Cardiac palpitation may occur if the cyst involves by pressure the heart or the cardiac nerves.

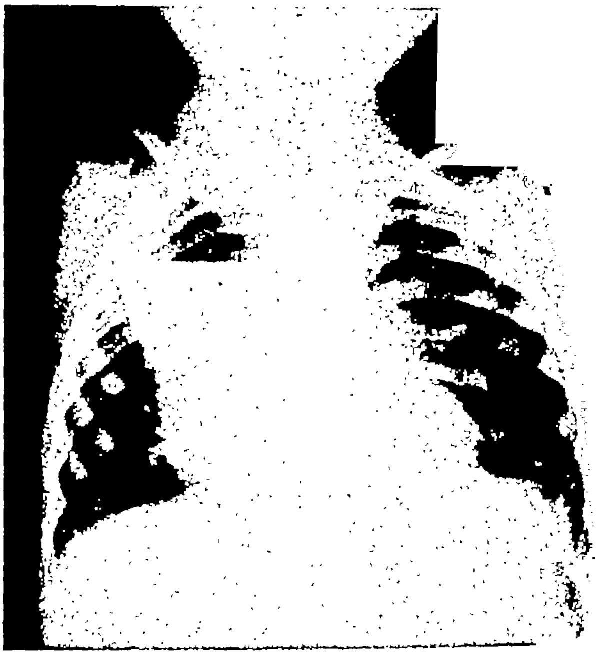

Fig. 1.—Posteroanterior roentgenogram showing fluid level on right side; note hemivertebrae in upper thoracic and cervical spine.

Hemoptysis has been observed occasionally and is caused by actual necrosis of the lung, by involvement of the bronchial vessels, or by the development of a fistula between the cyst and the air passages.

Chest pain occasionally occurs and is probably caused by pressure upon the parietal pleura and intercostal nerves.

Functional activity of the cyst may occur but will cause no symptoms other than hematemesis and then only if there is a communication with the esophagus. *Hematemesis* may be the presenting symptom and be particularly severe if there is peptic ulceration of the cyst wall. It is, of course, possible that in those cases with peptic ulceration of the cyst wall pain may ensue but this is conjectural only.

Melena, either as frank blood in the stools or in the form of tarry stools, may occur if there is a communication between the cyst and the esophagus. Ulcers of the cyst wall or a diffuse inflammatory reaction may cause bleeding and the discharge of blood in vomitus and stools.

Physical findings are those of a space-occupying mass within the chest together with those of the associated pneumonia or atelectasis. However, even a very large cyst may be associated with a surprising paucity of physical signs.

at the time this could occur, the assumption seems reasonable. As the result of changes in the anatomic relationships that accompany continued development, this organiser influence wanes thus allowing the stomach organisers to exert their influence to the completion of differential development even to include functional activity. With the formation of the mesenchymal coats (later muscular) and the development of the diaphragm, this exclusion is pinched off into the posterior mediastinum, but still retains sufficient attachment to the lower end of the esophagus to rotate to the right with the rotation of the stomach.''

This hypothesis has certain convenient aspects but remains ''an assumption'' and does not offer much information as to why these things happen or how. It must be admitted that although interruption of the orderly development of the germ layers does occur and by this occurrence does produce abnormalities and defects in the infant, the fundamental reason for such occurrence is not known.

Understanding of the results produced by congenital abnormalities is on much sounder ground. It is well appreciated that developmental aberrations of the embryo may produce pathologic states in the infant and adult that are of varying symptomatic magnitude. Thus a mediastinal cyst may seriously interfere with health and growth and even be a cause of death; or it may remain asymptomatic and be found by chance in an x-ray survey or at post-mortem.

Symptoms produced by these cysts result from pressure on neighboring structures and consequent interference with the functions of these organs or by functional activity within the cyst itself. Symptoms are of earlier occurrence and of greater magnitude in cysts with functional activity. The more nearly the structure of the cyst approximates that of the normal stomach, the more serious will be the symptoms caused by it.

Inasmuch as gastric cysts usually arise in the posterior mediastinum and encroach by their growth upon one or the other pleural space (usually the right), the pressure of their presence first will be apparent on the soft structures of the immediate vicinity. Among twenty-seven reported cases the cyst protruded into the right hemithorax in twenty-one cases; this is probably because the aorta is a fairly effective barrier against extension into the left hemithorax.

Interference with respiratory function is observed most commonly and consequently *dyspnea* is a frequent symptom; this results from pressure on the membranous posterior wall of the trachea and major bronchi and by interference with complete and free expansion of the lungs both by usurpation of the space provided for them and by production of atelectasis as a result of partial or complete bronchial occlusion.

Cough, usually dry and hacking, is caused by irritation of the contiguous trachea and bronchi. The cough may be productive if infection ensues distal to a point of partial bronchial obstruction.

Dysphagia in its true character of difficult swallowing is most uncommon since the liquid and soft foods of the infant diet will pass with ease through even a partially constricted esophagus. However, it is often observed that cian and surgeon, is scarcely necessary since almost all cystic tumors of the mediastinum should be removed surgically unless there is a serious contraindication.

The diagnosis may be made absolute by aspiration of fluid from the cyst and demonstration that the fluid is indeed similar to that produced in the stomach. This may be done by titration of its acidity and by the identification of pepsin or rennin. However, aspiration is not without danger of infection and leakage of corrosive gastric juice into the mediastinum or pleural cavity. It should, therefore, be done not to establish a precise pathologic diagnosis of the exact nature of a mediastinal cyst but only if doubt exists that the lesion is a cyst rather than a loculated pleural effusion. *In the event that aspiration is* deemed essential to diagnosis, the appropriate site for introduction of the needle should be determined by careful localization of the density in roentgenograms taken in at least two projections. The fluid found within the cyst may vary from thin and watery to thick creamy material that resembles pus. However, even a physical resemblance to pus seldom will confirm a diagnosis of empyema since usually the cellular content of the fluid will little resemble that of pus.

TREATMENT

The only effective method of treatment of gastric cysts of the mediastinum is surgical. Complete removal of the cyst in one stage is by far the most desirable method but occasionally expedience will dictate partial removal and destruction of the remaining mucosa or marsupialization with prolonged drainage and repeated efforts to destroy the mucosa. Certainly primary external drainage by thoracotomy or intercostal catheter is illogical and undesirable since the secreting mucosa is not destroyed by this method and eventually excision will have to be attempted through an infected field.

In infants the effects of the cyst are usually so severe as to jeopardize the life of the child and consequently removal of the cyst is imperative. With anesthesia adequate for intrathoracic operations there is no reason why the operation cannot be undertaken even in newborn infants. A transpleural approach through the side on which the cyst is most apparent allows generous exposure of the mediastium and permits the surgeon to dissect the cyst free from its often intimate attachments to the great vessels, the esophagus, and the lung. It would seem that an extrapleural mediastinotomy is unnecessarily restricting in exposure since the danger of an open pleura can readily be overcome by a competent anesthetist.

In adults gastric cysts are of infrequent occurrence and cause severe or life-threatening symptoms since they rarely contain actively secreting gastric mucosa. The rarity of gastric cysts in adults is, of course, an indication of the almost uniformly lethal nature of the anomaly in infancy. Asymptomatic cysts may very occasionally be found in routine x-ray surveys. Blades[2] has reported a series of 109 mediastinal tumors found in adults; although 34 of this number were benign epithelial cysts none contained gastric mucosa. Nevertheless, because of the great difficulty in determining the nature of a mediastinal tumor without histologic examination, removal of the tumor is advisable even though

Roentgenograms are indispensable in diagnosis of a mediastinal tumor but there are no roentgen signs that will lead unerringly to a precise diagnosis of a gastric cyst. The appearance on the roentgenogram is that of almost any solid or fluid-containing mediastinal tumor. The dense shadow of the gastric cyst is found in the posterior mediastinum and may extend into the right or left hemithorax. The cyst may contain air if there is a communication with the esophagus or trachea (Figs. 1 and 2). The form of the cyst tends to be spherical in the smaller ones and elongated in the long axis of the body in the larger cysts. The form is, of course, determined by the pliancy or immobility of the neighboring structures. Ancillary signs of the pressure effects of the cyst are varying degrees of atelectasis and obstructive or compensatory emphysema of the lung. Roentgenograms should be made in the upright position in frontal and lateral projections; oblique projections are occasionally useful in demonstrating smaller cysts. Esophagograms are of great value since displacement or distortion of the relatively mobile and pliant esophagus can be demonstrated readily without risk to the patient. There is little reason for using a bronchogram as a diagnostic aid since this procedure is very difficult in infants and is hazardous as well in those with respiratory embarrassment. Small cysts that cannot be demonstrated in conventional roentgenograms sometimes may be revealed by planigrams of the mediastinum.

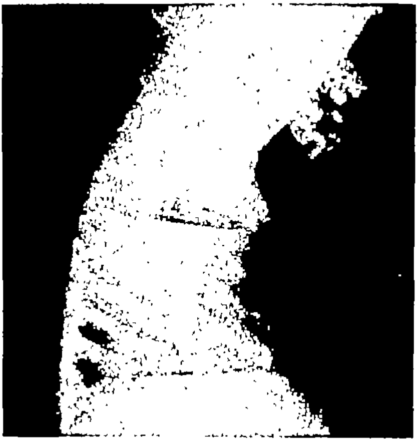

Fig. 2.—Lateral roentgenogram; fluid lies posteriorly.

Bronchoscopy and esophagoscopy may be helpful in excluding an endobronchial or endoesophageal lesion if such doubt exists; otherwise these examinations will only confirm the knowledge that there is a reduction in the lumen of the tube caused by an extramural mass.

All these diagnostic aids will lead only to the recognition of a probably cystic tumor of the posterior mediastinum without disclosing the true nature of the lesion. Indeed such accuracy of diagnosis, while pleasurable to the physia gastric cyst and none will survive with cysts containing actively secreting mucosa. From the fact that the successful cases have increased in recent years, it is apparent that, with increasing competence of thoracic surgeons and anesthetists, extensive intrapleural operations in infants can be undertaken more safely.

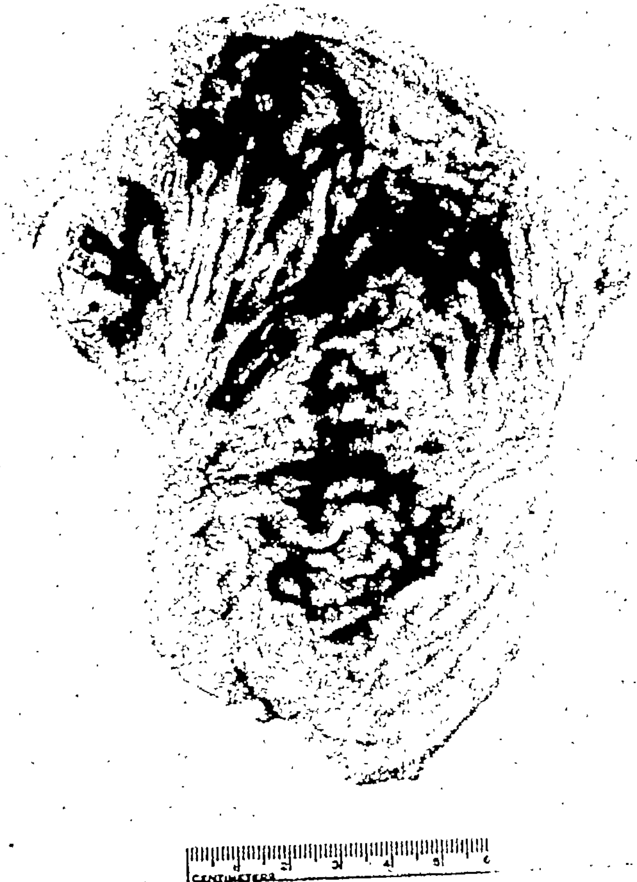

Fig. 4.—Interior of opened cyst; note gastric rugae and large ulcer at upper end.

CASE REPORT

C. M., aged 15 months, male. This child was delivered normally. Development was uneventful for nine months when he had moderate difficulty in eating and a slight cough. During the eleventh month he passed several tarry stools and soon thereafter vomited blood-streaked material. The next day he had a massive hemorrhage with bright red blood pouring from the mouth and rectum. He was hospitalized and given six whole blood transfusions. At that time a roentgenogram of the chest showed an area of increased density in the right hemithorax but the significance of this was not realized. A diagnosis of peptic ulcer was made at another hospital and the child was allowed to return home on a fluid diet. He continued to gain weight but was irritable, coughed frequently, and occasionally had difficulty in breathing in a recumbent position. He seemed to prefer lying on the right side.

At the age of 14 months he was acutely ill with fever, vomiting, diarrhea, and abdominal pain. Roentgenograms taken after this episode had subsided showed the density in the right hemithorax still present but with a fluid level now apparent. Gastrointestinal x-rays and a barium enema were normal. At the time of admission to the Albany Hospital on Feb. 6, 1947, physical examination was normal except for the chest. Expansion the patient is in perfect health and without symptoms at the time it is found. In such a case complete removal is most desirable. Occasionally it may be permissible, and indeed sometimes essential, to leave behind a portion of the cyst wall if its removal from the great vessels or other contiguous structures would be too hazardous. In such circumstances the mucosa itself may often be removed or destroyed by an escharotic agent after the cyst has been opened.

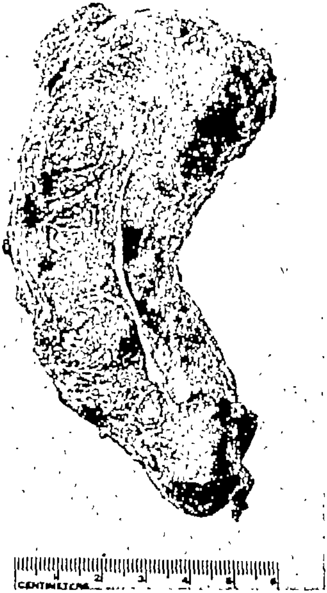

Fig. 3.—External appearance of cyst in its distended state; note similarity to normal stomach with pylorus at lower end.

In seventeen of the reported cases operative procedures were carried out; these have been reported by thirteen authors.[3, 5, 6, 12, 13, 16, 17, 19, 22, 25, 30, 31, 32] Complete excision, either as a primary procedure or secondary to drainage or marsupialization of the cyst, was attempted or carried out in twelve cases; of this number seven patients survived and five died as a result of the operation. In five of the cases other operative procedures (exploration alone, marsupialization and cautery destruction of the mucosa, paraffin plombage) were done; of this group two patients survived and three died. It is to be noted that of the seven patients who recovered after excision, two were adults with cysts in which only remnants of gastric mucosa were found.

It is apparent from these figures that operation is hazardous. On the other hand, without operation only a very few infants will survive to adult life with

23 degrees. Tests for rennin and pepsin were not done. The nature of the fluid at once confirmed a diagnosis of gastric cyst of the mediastinum and surgical removal was decided upon.

Preoperatively the patient was given a transfusion of whole blood and received penicillin for several days. On Feb. 18, 1947, a thoracotomy was done under endotracheal anesthesia. The right sixth rib was removed subperiosteally and the tumor exposed through a transpeural approach. The lung appeared normal although partially collapsed and was free of adhesions except for the apical portion of the upper lobe which was adherent to the mediastinal pleura overlying the cyst. It extended from a point high in the neck to the diaphragm, where it ended in a firm cord. The blood supply was derived from the mediastinum and directly from the aorta. The esophagus was identified and found to lie to the left and anterior to the cyst. No connection could be found between the cyst and the esophagus, although one may have existed high in the neck. The mediastinal pleura was incised and the cyst freed by combined sharp and blunt dissection. The mucosa was completely removed from the pedicle which extended into the neck, and the pedicle itself was then ligated with silk sutures. The pleural cavity was lavaged with copious amounts of saline solution and the mediastinal pleura closed loosely with interrupted sutures. The lung was expanded and a small Pezzer catheter was placed through the ninth interspace posteriorly for postoperative drainage. Penicillin, 200,000 units, was instilled into the pleural cavity and the wound closed in layers with interrupted silk sutures.

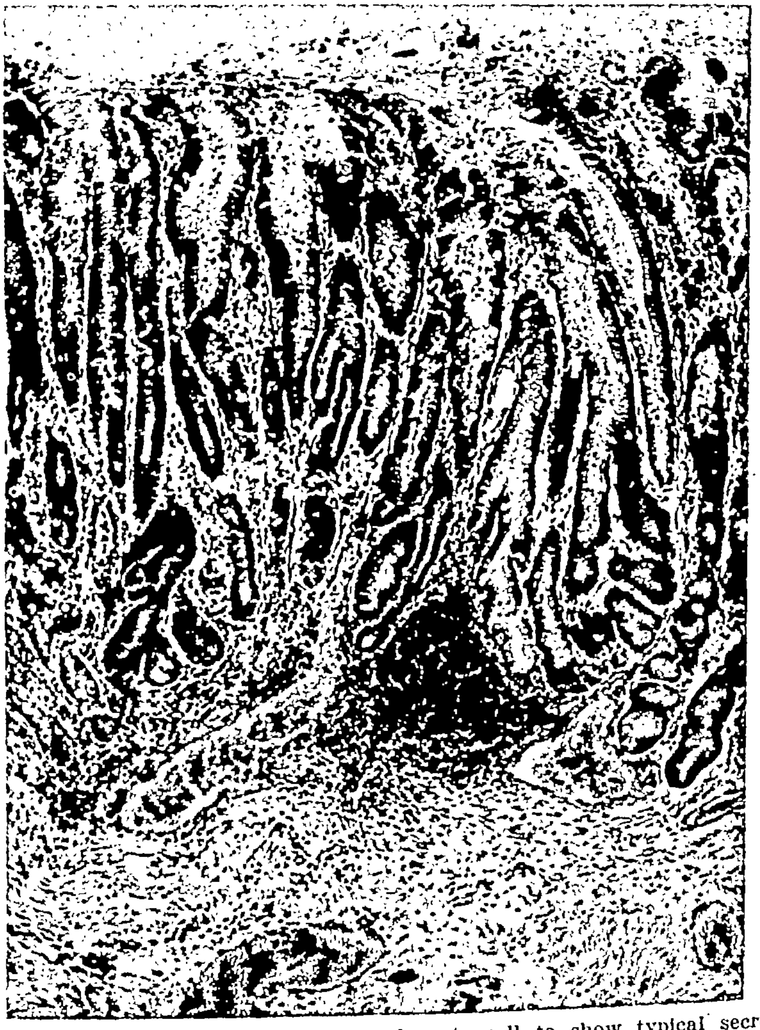

Fig. 6.—High-power magnification of mucosa of cyst wall to show typical secreting gastric mucosa.

was equal bilaterally, the percussion note was resonant throughout, and breath sounds were bronchovesicular with numerous moist râles and rhonchi. The adventitial sounds were more marked at the right base. He had at that time a mild upper respiratory infection. Urinalysis was normal; the red blood cell count was 4,370,000 with 17 Gm. of hemoglobin; the white blood cell count was 31,500 with 65 per cent polymorphonuclear leucocytes. Roentgenograms of the chest showed an increased density through the upper portion of the right pulmonary field extending downward close to the cardiac shadow to the diaphragm with a fluid level opposite the first anterior rib. In the lateral projection, the greatest opacity was posterior (Figs. 1 and 2). Incidental findings were spina bifida of the lower cervical vertebra and a hemivertebra in the upper thoracic region. Fluoroscopic examination of the chest showed both leaves of the diaphragm to be moving normally. A barium meal failed to reveal any communication between the esophagus and the cystic tumor in the mediastinum. The stomach was normal in position and appearance.

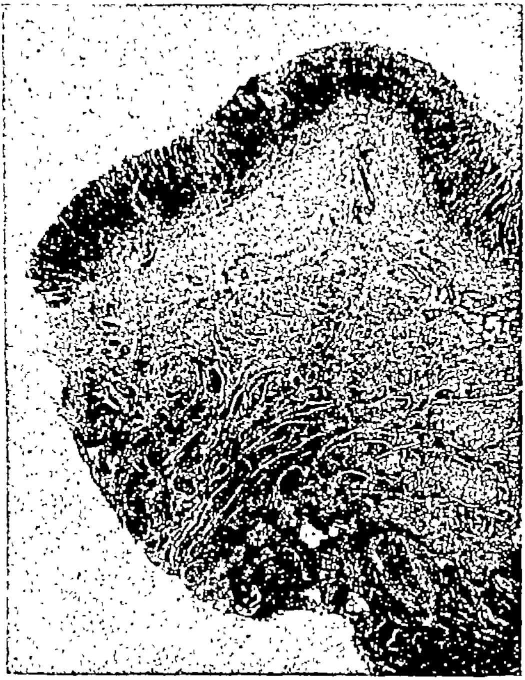

Fig. 5.—Low-power photomicrogram showing mucosa, submucosa, and two muscle layers of cyst wall; note similarity to normal stomach.

Possible diagnosis of a cystic tumor of the mediastinum or a loculated empyema with a bronchopleural fistula were considered and it was felt that thoracentesis was advisable since ultimate treatment would depend to a large extent on the nature of the fluid. Fifty cubic centimeters of thin, brownish fluid containing darker solid particles were aspirated. This fluid gave a positive guiac test and had a free acid of 12 degrees and a total acid of

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The cyst measured 14 by 5 by 1.5 cm. in size and resembled grossly a normal infant stomach. The wall was uniformly resilient and averaged .3 cm. in thickness. The inner surface consisted of mucosa in rugal folds typical of stomach. A .5 cm. ulcer was found at the upper end of the cyst. The cyst contained about 75 c.c. of yellowish fluid which was negative for occult blood and had 18.6 degrees free and 32.4 degrees total acid (Figs. 3 and 4).

Microscopic Descriptions.—Sections from various portions of the wall of the specimen showed a typical secreting gastric mucosa. In several situations collections of acute inflammatory cells were scattered throughout the mucosal glands. A small mucosal ulcer covered by fibrinous exudate was present. Mucosal capillaries were congested. The submucosal tissues were slightly fibrosed. The inner musculature, circular layer, was composed of a histologically normal, smooth muscle. The outer musculature, the longitudinal layer, did not appear unusual and was slightly thicker than the inner circular layer. The outer tissue, the serosa, was fibrosed and focally hemorrhagic. Arteries and arterioles in all layers of this cystic structure were not unusual (Figs. 5 and 6).

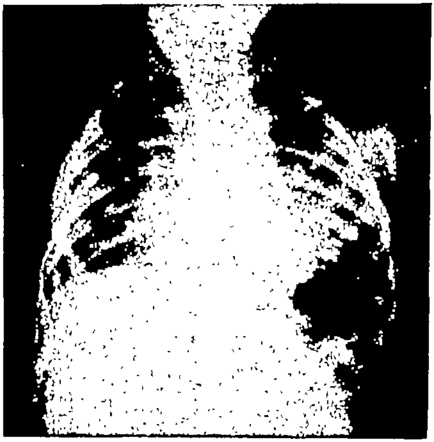

Fig. 7.—Postoperative roentgenogram showing only slight residual pleural thickening.

Diagnosis.—Diagnosis was gastric cyst of mediastinum with a small ulceration of mucosa.

The postoperative course was complicated by development of a pleural effusion on the right side but this responded to frequent aspirations and chemotherapy.

Six months after operation the boy was in good health with no indication of other cysts below the diaphragm. Postoperative roentgenograms (Fig. 7) showed only slight pleural thickening.

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The patient was a well-developed, well-nourished, white woman who did not appear to be ill. There was no cyanosis. Examination of the head, eyes, ears, nose, and throat was essentially negative. The heart was not enlarged to percussion and no murmurs were heard. Radial pulses were equal and regular. The chest moved equally and adequately with respiration. The percussion note was everywhere resonant and the lung bases descended fully and equally. The breath sounds were vesicular throughout but slightly distant over the right

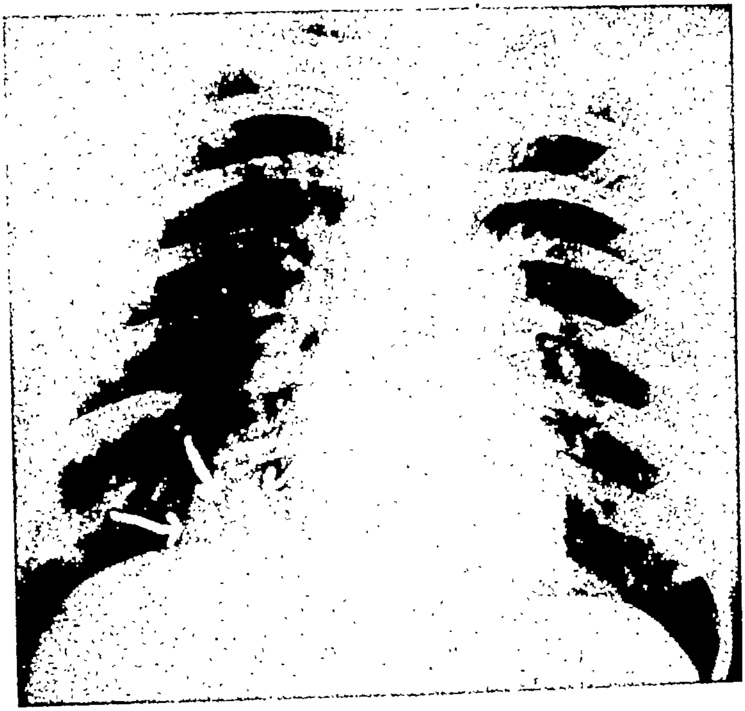

Fig. 1.—Roentgenogram of chest in patient with solitary xanthoma of lung.

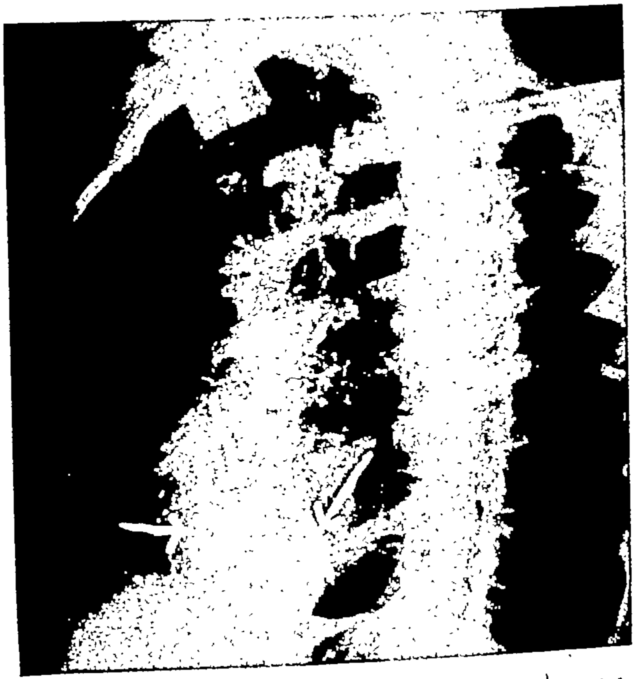

Fig. 2.—Bronchogram demonstrating xanthoma in right lower lobe of lung.

SOLITARY XANTHOMA OF THE LUNG

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and Torrence P. B. Payne, M.D.
Baltimore, Md.

WE have recently had an opportunity to observe a clinically benign tumor of the lung in a young woman. After a successful lobectomy with removal of the lesion, pathologic study showed this tumor to be a so-called "xanthoma." Since we have been unable to find a similar case previously recorded, this case is reported in detail.

CASE REPORT

F. M., a 34-year-old white housewife, first came to the outpatient department of the Johns Hopkins Hospital on April 3, 1946, for examination as recommended by her family physician.

Family history was noncontributory. The patient's *past health* had been good. Ten years previously she had had an episode of albuminuria and edema of the face. This was not associated with pregnancy and cleared without specific therapy in about ten days. Eleven years prior to admission she had an attack of mild left-sided pleurisy lasting about one week and unassociated with cough, fever, weight loss, or hemoptysis. For the past five years she had had occasional ankle edema after standing. The patient denied any exposure to tuberculosis.

The present illness was dated from September, 1945, at which time she had mild hemoptysis for five days. This was intermittent and associated with pain in the right supraclavicular region. It was not associated with fever, sweats, weight loss, or malaise. Shortly after this a chest x-ray taken by the family physician is said to have shown a lesion in the lung, not thought to be tuberculous.

Since September, 1945, the patient had been completely asymptomatic; there had been no further hemoptysis, and no pain, cough, weight loss, or sweats.

Physical examination upon admission to the outpatient department was completely negative except for slight impairment of breath sounds over the right lower chest.

A chest x-ray taken at this time (Fig. 1) revealed a normal cardiovascular shadow. In the right cardiophrenic angle a circular circumscribed lesion was apparent. On fluoroscopy this was found to be in the anterior portion of the right lower lobe. The remainder of the lung fields was clear. Bronchoscopy on two occasions failed to show any endobronchial pathology. Bronchograms showed no communication of the mass with any bronchus and were normal in all other respects (Fig. 2).

A tuberculous lesion was strongly suspected and for this reason the patient was followed carefully for a period of ten months. Serial x-rays during this period did not show any change in the size, shape, or position of the mass. Repeated smears and cultures of the sputum failed to reveal tubercle bacilli. The Mantoux test was only slightly positive after forty-eight hours with 0.1 c.c. of 1:1,000 old tuberculin.

Accordingly a diagnosis of lung tumor, probably benign, was made and on Feb. 3, 1947, the patient was admitted to the surgical service of this hospital.

During the period of observation in the out-patient department the patient had remained entirely asymptomatic.

Physical Examination.—The temperature was 99.2° F.; pulse, 88; respiration, 22; blood pressure, 96/70.

From the Departments of Surgery and Surgical Pathology of the Johns Hopkins University School of Medicine and the Johns Hopkins Hospital.

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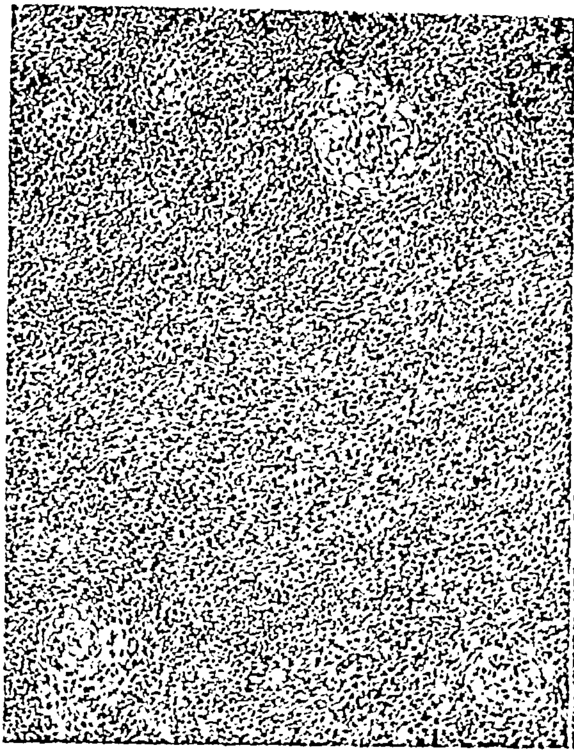

Fig. 4.

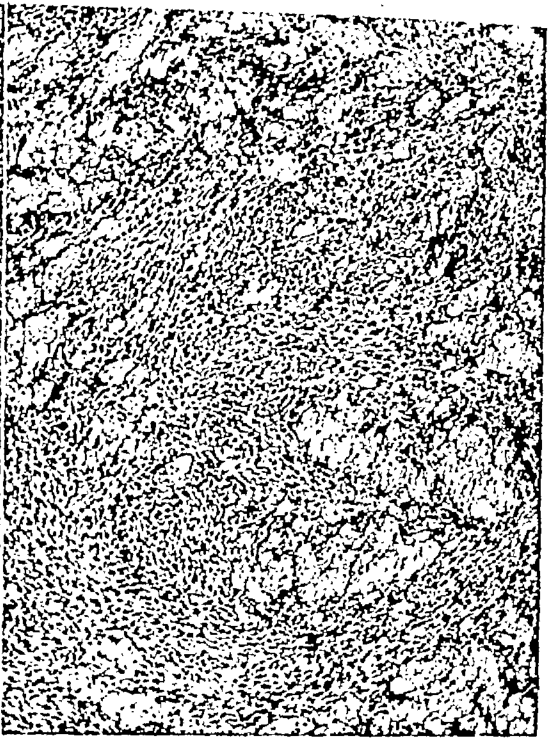

Fig. 5.

Fig. 4.—Luxuriant growth of oval or spindle-shaped cells with small groups of xanthoma cells.

Fig. 5.—Xanthoma cells scattered singly or in groups.

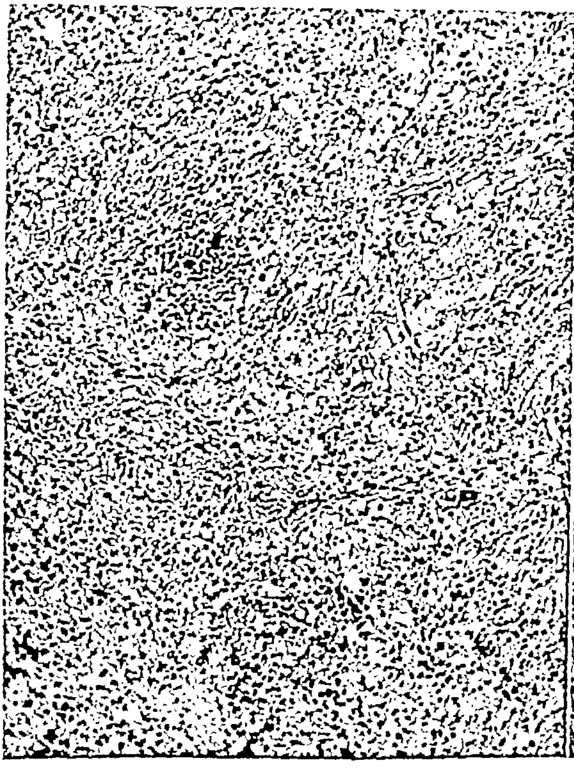

Fig. 6.

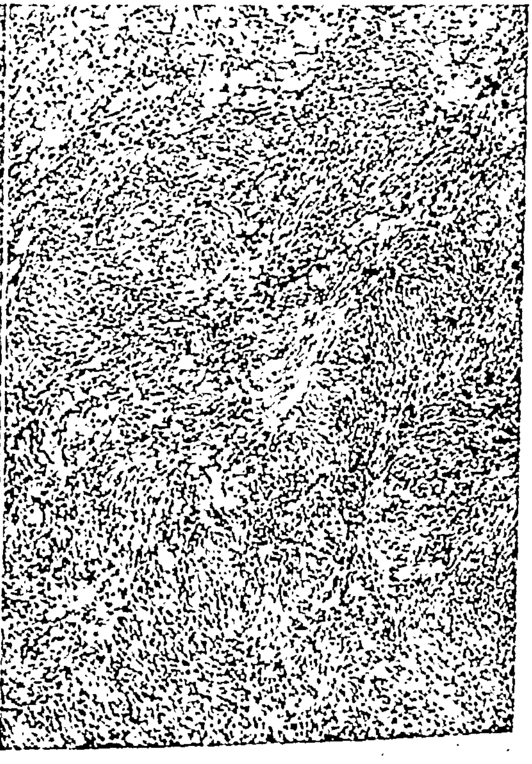

Fig. 7.

Fig. 6.—Area showing a preponderance of xanthoma cells. One giant cell and a small collection of lymphocytes are present.

Fig. 7.—Interlacing bands reminiscent of the structure of a *neurinoma.*

lower chest posteriorly. There was no clubbing of fingers or toes. The remainder of the physical examination revealed no abnormalities.

Laboratory Studies.—Urinalysis was negative; hemoglobin 13 grams per cent; leucocyte count was 6,000 with normal differential; sedimentation rate (corrected) 24.0 mm. per hour; icteric index 6.0; sputum smear revealed no acid-fast organisms.

Operation.—On Feb. 5, 1947, Dr. Alfred Blalock, using endotracheal cyclopropane-ether anesthesia, performed a thoracotomy through a right posterolateral incision, resecting a portion of the sixth rib posteriorly. A few filmy adhesions were present between the lung and the chest wall. The upper and middle lobes were normal in appearance and consistency. The basal segment of the right lower lobe contained a hard mass the size of a large lemon which was completely contained within the parenchyma of the lobe. No other masses were palpable and no hilar nodes were felt. Accordingly a right lower lobectomy was performed and the chest closed without drainage. The patient withstood the procedure well.

Course.—The postoperative course was extremely smooth. The patient was ambulatory and comfortable by the second postoperative day. X-rays revealed good expansion of the remaining lobes with a minimum of fluid. Thoracentesis was not necessary. She was given penicillin 240,000 units daily for nine days.

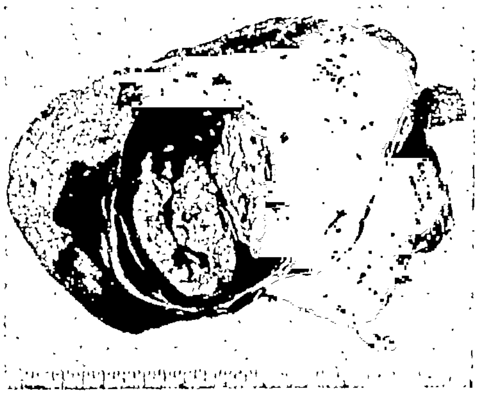

Fig. 3.—Photograph of resected right lower lobe (patient F. M.) with incision into substance of lobe exposing well-circumscribed xanthoma.

Because of the xanthomatous appearance of the tumor (Fig. 3), numerous postoperative laboratory procedures were carried out. Cephalin flocculation and thymol turbidity were within normal limits. Serum nonprotein nitrogen was 41 mg. per cent; cholesterol 200 mg. per cent; total serum protein 6.7 Gm. per cent with albumin 4.3 Gm. per cent and globulin, 2.4 Gm. per cent; amylase 233 mg. per cent reducing substance; phosphate 4.0 mg. per cent and alkaline phosphatase activity 2.0 Bodansky units. Bilirubin was 1.6 mg. per cent total, 0.9 mg. per cent direct. Bromsulfalein showed 2.0 mg. per cent retention. Intravenous urograms showed normal collecting system and ureters. Serologic tests for syphilis were negative. No evidence of generalized xanthomatosis could be detected. Liver and spleen were not palpable and no suggestive cutaneous lesions were present. Roentgenograms of the skull and long bones showed no abnormalities.

The patient was discharged asymptomatic on the thirteenth postoperative day. Physical examination of the chest at this time showed decrease in breath sounds at the right base with slight impairment of percussion. She has remained in good health in the nine months since discharge from the hospital.

A REPORT OF A CASE OF LOCALIZED BRONCHOPULMONARY MONILIASIS SUCCESSFULLY TREATED BY SURGERY

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NEWINGTON, CONN.

INTRODUCTION

Bronchopulmonary moniliasis was first described by Castellani[1] in Ceylon in 1905. Many of his patients contracted the disease by inhaling tea dust in factories. In 1906 he found mycelial filaments and yeastlike bodies in the sputa of men suffering from tea tasters' cough. The clinical picture closely resembled tuberculosis, varying from mild cough to fever, hemoptysis, emaciation, and death. He struck a note of caution in making the diagnosis because monilia, which may exhibit all degrees of pathogenicity, are frequently found in the oral cavity of man. He described four pathogenic species: Monilia tropicalis Castellani, Monilia pinoyi Castellani, Monilia Krusei Castellani and Monilia metalondinensis Castellani, but indicated that other species with the same biochemical reactions may be nonpathogenic. He felt that pathogenic forms could be differentiated by intrapulmonary inoculation into rabbits with subsequent formation of characteristic pulmonary nodules.

In 1915 Boggs and Pincoffs[2] reported the first case of bronchopulmonary moniliasis in this country with post-mortem findings. Up until 1931 only five cases of bronchopulmonary moniliasis were confirmed by post-mortem examination. One of the most complete descriptions was made by Warr.[3] The disease may manifest itself in protean ways and affect the following structures: (1) tonsils, (2) bronchi, (3) conjunctiva, (4) intestinal tract, (5) ears, (6) urethra, (7) skin, (8) central nervous system. In addition, five instances of blood stream infection, all occurring in drug addicts, have been reported. Wessler and Browne[4] reported complete recovery of a patient with monilial bacteremia during the use of NaI intravenously and thymol and KI orally. Hiatt and Martin[5] reported cure of a patient treated with anticandida rabbit serum, after iodides had been discontinued because of severe skin eruptions. Intravenous gentian violet has also been used. All forms of therapy have been only sporadically successful. Surgery has not been previously described as a therapeutic measure. The following case report represents the first successful surgical extirpation of localized bronchopulmonary moniliasis.

CASE REPORT

A 22-year-old, well-developed, white man was admitted to the hospital on Feb. 24, 1947, with a history of hemoptysis for three months. Three months before admission he developed

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*Pathologic Study.**—

Gross description: The specimen consists of the lower lobe of a lung. The pleural surfaces are smooth and pink. The lung tissue is only slightly crepitant and within it a firm, round mass can be felt. On section this mass appears to be well circumscribed (Fig. 3), measures 4.5 cm. in greatest diameter and is composed of somewhat friable, yellow tissue, which has a smooth chalklike cut surface. In the center of the mass there is apparently a thin-walled blood vessel measuring about 1 cm. in greatest diameter and filled with blood clot. Small areas of hemorrhage are also seen around the periphery of the mass. The surrounding lung tissue is compressed and at one point only a thin layer about 2 mm. in thickness separates the tumor from the pleural surface. Representative blocks are taken for microscopic study.

Microscopic description: All of the sections show a luxuriant growth of oval or spindle-shaped cells (Fig. 4) lying on a background of eosinophilic fibrillary collagen. Scattered among them singly or in groups (Figs. 4, 5) are large, round, or polyhedral cells which have a small dark nucleus and foamy cytoplasm which stains deeply with sudan IV and is doubly refractile. Lymphocytes are scattered lightly throughout the sections and an occasional plasma cell and eosinophile are seen. A few multinucleated giant cells are also present (Fig. 6). In a few areas the collagenous material has a tendency to form interlacing bands reminiscent of the structure of a neurinoma (Fig. 7); no nervous elements can be demonstrated, however, either by the Masson trichrome stain or by the Wilder method. There are a few small areas of hemorrhage and foci of hemosiderin-laden macrophages are found scattered in the sections. The grossly described blood vessel in the center of the mass is seen to consist of an area of laked red blood cells, hemosiderin, and cholesterol clefts surrounded by hyaline scar tissue. Around the growth there is a definite connective tissue capsule which in some places is thin and partially broken through. Elastic stains do not reveal any lung framework within the mass itself.

Final Diagnosis.—Xanthoma in lung.

COMMENT

Considerable confusion exists concerning the nature and etiology of the disturbances of lipoid metabolism manifested by xanthomatous masses, whether local or generalized. Gruenfeld and Sielig[1] in 1934 and Thannhauser and Magendantz[2] in 1938 made exhaustive studies of the xanthomatous diseases. In general these authors consider the various forms of xanthoma to represent metabolic disturbances rather than neoplastic processes. They classify the xanthomatous diseases as (1) primary xanthomatosis with and without hypercholesterolemia, (2) secondary xanthomatosis associated with lipemia, and (3) localized xanthoma cell formation in true tumors.

In the case reported here there was no evidence of general metabolic disturbance as manifested by diabetes, hypercholesterolemia, or lipemia. No xanthomatous lesions were present in the skin and no osseous changes were demonstrable. Therefore, it would appear that the solitary tumor of the right lower lobe of the lung in our patient represents either a xanthomatous deposit of a primary nature or xanthomatous replacement of an underlying neoplasm, no identifiable remnants of which remain.

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*By T. P. B. Payne.

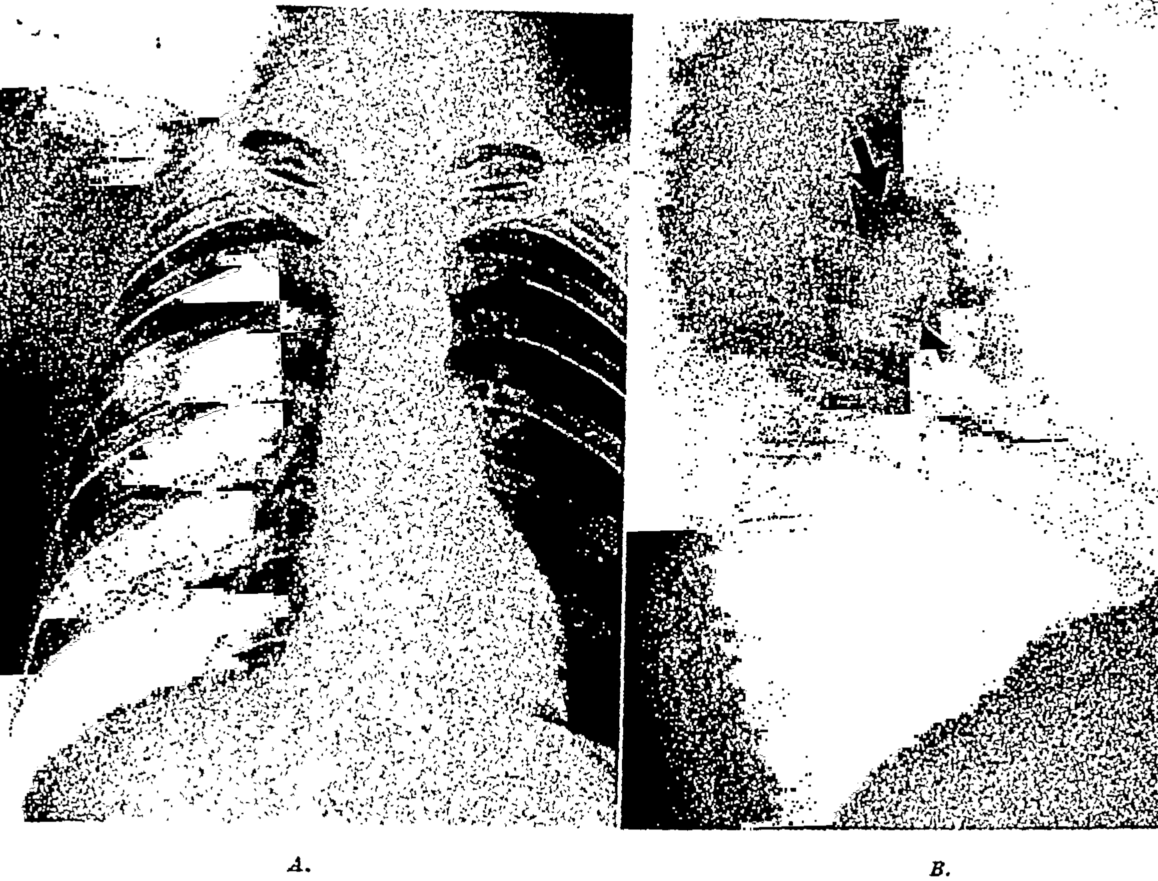

Fig. 1. *A* and *B*.—Anteroposterior and lateral x-ray views of the lungs reveal an ovoid area of infiltration in the axillary segment of the subapical division of the right upper lobe.

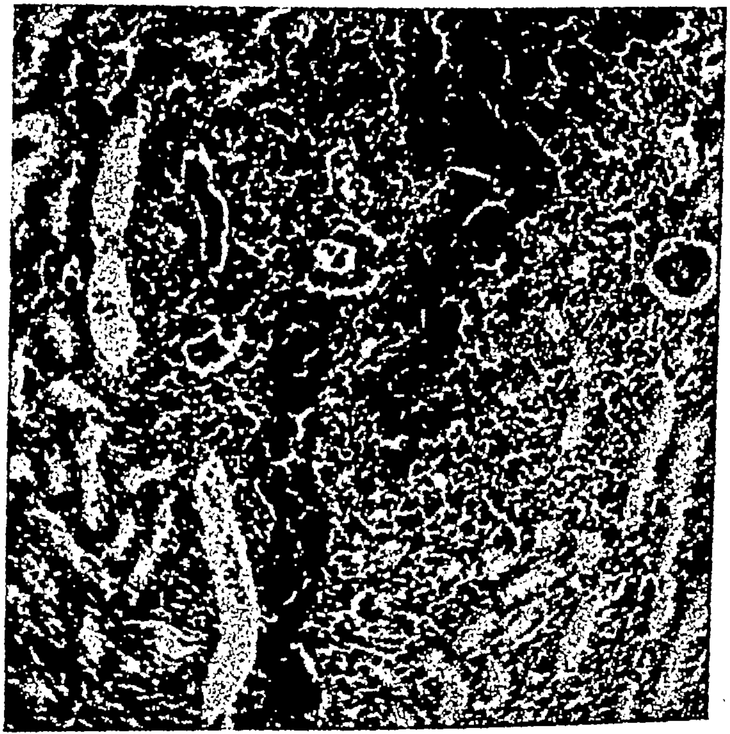

Fig. 2.—Low-power photomicrograph of rabbit's kidney, showing granuloma produced by intravenous injection of suspension of monilia grown from patient.

a scanty cough with fever, and called a physician who confined him to bed for one week with "virus pneumonia." Because of continued cough with daily production of about one-half ounce of sputum, occasionally blood-streaked, roentgenograms of the chest were taken in November, 1946, and January, 1947. They revealed a persistent opacity in the upper lobe of the right lung and the physician made a tentative diagnosis of pulmonary tuberculosis. The patient had no dyspnea or easy fatigability and had gained two pounds in weight since the onset of the illness.

Physical examination revealed a well-nourished patient who did not appear ill. The temperature was 98.4° F. and the pulse rate was 76 beats per minute. Examination of the lungs was negative. X-ray views of the chest revealed an ovoid area of infiltration 3½ cm. in diameter in the axillary segment of the subapical division of the upper lobe bronchus (Fig. 1).

Laboratory studies revealed that the red cell count was 4,700,000, hemoglobin 81 per cent, and the white cell count 6,400 with a normal differential. Tuberculin intradermal test (PPD) was negative in dilutions of 1:10,000 and 1:1,000. Six concentrated specimens of the sputa and of the gastric juice were negative for tuberculosis and pathogenic fungi. A guinea pig inoculated with the sputum was autopsied in the eleventh week and tuberculosis could not be demonstrated. Coccidioidin skin test (1:1,000) was negative.

Sputum collected on May 13 and May 19 and cultured on Sabouraud's medium grew out numerous yeastlike colonies, which after subculture on sucrose, maltose, and lactose showed the cultural characteristics of *Candida albicans*, including branching forms on stab preparations.* On May 16, examination of the right chest was negative for fungi. On June 2, 1 c.c. of the culture of C. Albicans from the sputum was injected into a rabbit's ear vein. On June 10, autopsy of the animal revealed numerous bilateral renal granulomas, which were firm, yellow-white, and measured up to 1 cm. in diameter. Microscopically they consisted of acute granulomas in which neutrophilic and eosinophilic polymorphonuclear leucocytes predominated (Fig. 2). The surrounding tubules were filled with similar exudate.

Clinical Course.—The patient had an afebrile course but continued to raise about one-half ounce of sputum which was occasionally blood-streaked. Bronchoscopy and bronchograms were noncontributory. Because a lung abscess could not be ruled out, he was given a course of sulfadiazine (6 Gm. daily) and penicillin up to one million units daily. In addition, aerosol penicillin (30,000 units every four hours) was tried without any resultant diminution in the size of the lesion. Since carcinoma of the lung was a distinct possibility and since the lesion, if not malignant, might prove amenable to surgical extirpation, an operation was performed on May 2, 1947. The pleura was opened through the bed of the fourth rib. A circumscribed, somewhat firm lesion was observed in the axillary segment of the subapical division of the right upper lobe in close proximity to the oblique fissure. Since the lesion was firmly adherent to the parietal pleura, the latter was removed with the diseased portion of the lung. A wedge excision of the diseased axillary segment, which included the segmental bronchus, was performed. The edges of the defect were closed with short, running sutures of No. 00 catgut. A No. 20 Foley catheter was left in the pleural space and the wound was closed in layers with silk.

The patient made an uneventful postoperative recovery. On two occasions 350 c.c. of sanguineous, sterile fluid were removed from the pleural cavity. The patient was discharged on the nineteenth postoperative day. He was completely asymptomatic when seen one year later.

Pathology Report.—The specimen consisted of a 5.5 by 6 by 3 cm. wedge-shaped mass of lung tissue, to which was adherent a 4 by 1.5 by 0.7 cm. strip of muscle (Fig. 3). The lung was congested, red, and atelectatic. The base of the wedge consisted of both pleural layers, to which intercostal muscle was adherent. The apex of the specimen presented a 5 mm. channel with a 1 mm. thick, white wall, suggestive of a bronchus. Through this

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*Because of the highly technical nature of fungus identification, a culture was submitted to Dr. Norman F. Conant of Duke University, who identified it as *Candida* (monilia) *albicans*.

opening projected a white, translucent, gelatinous, shiny membrane. The channel opened into a thick-walled, cystic structure measuring about 1.5 cm. in diameter and lined by the same translucent material, resembling a "thrush" membrane, which was removed, leaving a roughened, pebbly surface with numerous blood clots. The wall measured up to 1 cm. in thickness, was firm, and contained many small, yellow foci.

On microscopic examination (Figs. 4, and 5), the wall of the cavity was found to be lined by granulation tissue with numerous capillaries and fibroblasts and heavily infiltrated with plasma cells, and less heavily with lymphocytes, neutrophilic and eosinophilic polymorphonuclear leucocytes. The outer portion of the wall consisted of a layer of collagenous, fibrous tissue, in which eosinophiles and lymphocytes were the predominant white cells. The surrounding lung tissue was congested and atelectatic. About the blood vessels and small bronchi, lymphocytes formed follicles which showed considerable germinal activity. Adjacent to these follicles, the alveoli were frequently lined by cuboidal cells. Some of the alveoli and bronchi contained "dust cells" and vacuolated monocytes; others were filled with red blood cells and neutrophiles. In the area between the cavity and the pleura, the lymphoid accumulations were particularly dense. Only a few bronchi and channels lined by cuboidal cells remained. The channel at the apex of the specimen was lined by bronchial epithelium, which became ulcerated as it joined the cavity. The pleural layers and intercostal muscles were fused by vascular fibrous tissue, through which the blood vessels coursed in a radial direction. Lying loosely within the cavity there was a network of fungal mycelia, closely surrounded by neutrophiles. Frozen sections and hanging drop preparations of the loose, white membrane revealed that it was a growth of fungus, having the segmented, branching mycelia and chlamydospores characteristic of *C.* (monilia) *albicans.*

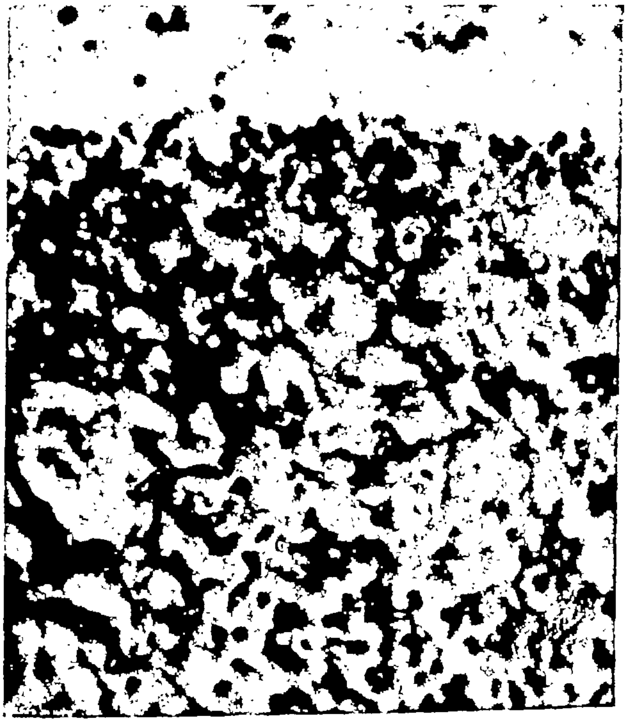

Fig. 5.—Oil immersion photomicrograph of mass of mycelia shown in Fig. 3.

COMMENT

Bronchopulmonary moniliasis is a difficult diagnosis to make. Skin tests are equivocal.[6, 7] Monilia present in the sputum may be nonpathogenic or may be a secondary invader. Discovery of the characteristic

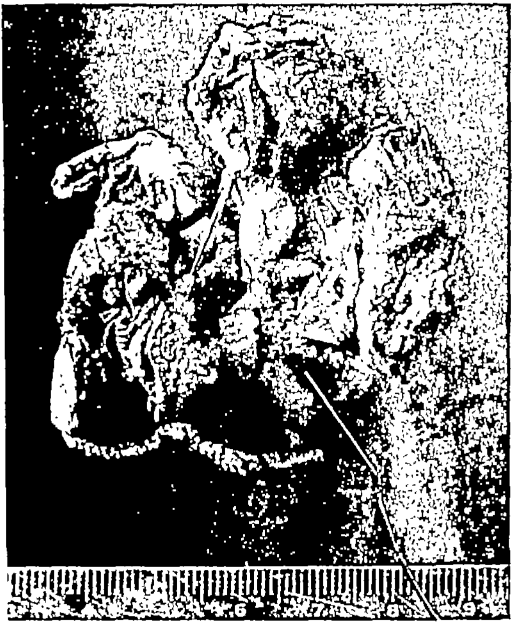

Fig. 3.—Lung specimen, showing bronchus at entrance to cavity, which is filled with semi-attached, gelatinous, monilial membrane.

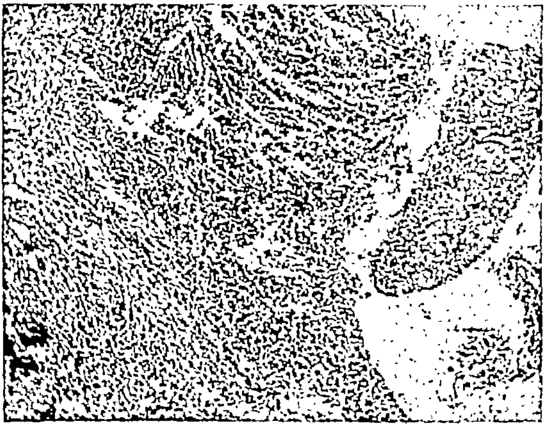

Fig. 4.—Low-power photomicrograph of granulation tissue wall of lung cavity, showing loose mass of mycelia in the cavity.

CONSTRICTIVE PERICARDITIS WITH OBSTRUCTION OF PULMONARY VEINS

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SINCE Chevers'[1] excellent description of chronic pericardial disease in 1842, there have been many publications about this disease. Most authors separate the disease into constrictive pericarditis, a fibrous process of the pericardium without external adhesions, and chronic mediastinopericarditis, a process in which the external adhesions are predominant. In some cases such a clear-cut distinction cannot be made.

Effective surgical therapy for constrictive pericarditis had not been accomplished until three decades ago. Brauer[2] in 1902 described a rib removal procedure called cardiolysis. This, however, was of value only in the mediastinopericarditis group despite its indiscriminate usage. Delorme[3] in 1898 proposed removal of the constricting pericardial sac, but reports of pericardial resection did not appear until 1920. In the ensuing ten years there were reports of surgical cures by Rehn,[4] Volhard and Schmieden,[5] Sauerbruch,[6] Churchill,[7] and Beck.[8] In the last two decades there has been more widespread use of this procedure.

In a typical case of constrictive pericarditis there are symptoms and signs of right-sided heart failure in a patient with a small quiet heart. The pericardial scar limits diastolic filling, thereby decreasing stroke volume. In most cases this has a marked effect on the systemic venous circulation, producing persistent serous effusions, edema, and elevated venous pressure. There is also tachycardia, low pulse pressure, and pulsus paradoxus. Detailed physiologic, clinical, and surgical discussions of this condition and its variations have been published by Beck and Griswold,[9] White,[10] Heuer and Stewart,[11] Blalock and Burwell,[12] and Sellors.[13]

Different classifications and concepts of pathogenesis have been expressed through the years by Pick,[14] Kelly,[15] Rolleston,[16] Curschmann,[17] Rothstein,[18] and others. Constrictive pericarditis has been described under other names such as Pick's disease, adhesive pericarditis, and polyserositis. Much of this variation is probably due to the unknown etiology of the majority of cases reported.

Most writers report approximately 20 per cent of their cases as proved tuberculosis (Cole and associates[19] and Harrison and White[20]). In contrast, Blalock and Burwell[12] reported the tubercle bacillus as etiologic agent in 64 per cent of their twenty-eight surgical cases. Another group of cases are regarded as sequelae of pyogenic pericarditis. Rheumatic pericarditis is now

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membrane of monilial infection in the diseased portion of the lung is the most valid diagnostic procedure. The appearance of a cavity connecting with a bronchus, filled with a gelatinous, white membrane and adherent to the chest wall, corresponds closely to the necropsy findings described by Warr.[3] Microscopic examination of the membrane proved the existence of numerous fungal elements, identifiable as C. (monilia) *albicans.* Attempts to demonstrate other agents by bacteriologic and histologic methods failed. There was also failure to elicit a history of any antecedent disease. Further evidence of the association of monilia with the pulmonary lesion was the consistent appearance of the typical organisms in the sputum. These organisms from the sputum injected intravenously into a rabbit's ear[8] produced granulomas of the kidneys resembling the nodules in the lungs of a rabbit produced after intrapulmonary inoculation by Castellani.[1] Clinically, the sputum was scanty. The glairy, sticky quality with a sweet or yeastlike odor described by others was not present. The gross and microscopic picture of the lesion, the demonstration of monilia in the membrane lining the cavity, the finding of monilia in the sputum by direct examination and culture, a positive virulence test in an inoculated rabbit, and the failure to demonstrate any other causative agent or to elicit a history of antecedent disease are the reasons for calling this a case of primary bronchopulmonary moniliasis. Only the lung was invaded in this case.

Vaccine and drug therapy have been only sporadically successful.[1, 4, 5, 9, 10] *Surgical intervention should be considered as an effective therapeutic procedure* in the treatment of localized bronchopulmonary moniliasis.

SUMMARY

The first case of primary bronchopulmonary moniliasis successfully treated by surgical excision has been reported. The patient has shown no clinical or x-ray evidence of recurrence of the disease during the year following operation.

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and mediastinal tumor were considered possible diagnoses from the x-ray appearance (see Fig. 1, *A* and *B*).

Special Tests.—The venous pressure in the right antecubital vein was 319 mm. and 320 mm. of water on two measurements. Vital capacity was 1.5 liters. The electrocardiogram was interpreted as showing right axis deviation. There was low voltage of the ventricular complexes.

Working Diagnosis.—A working diagnosis was made of tumor or cyst in mediastinum or pericardium with impingement upon or obstruction of the pulmonary circulation.

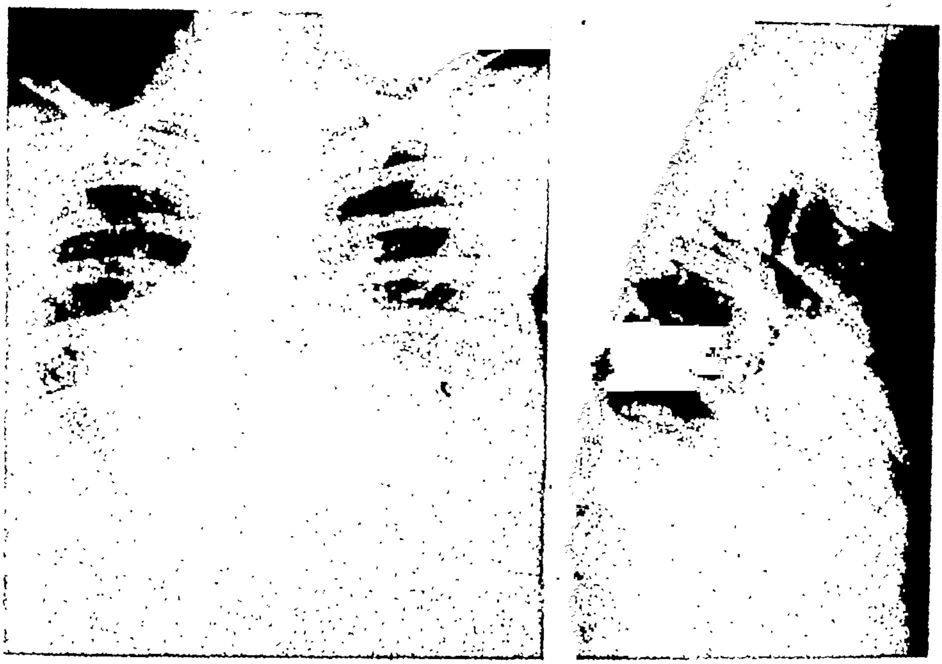
A. *B.*

FIG. 1.—*A*, Chest roentgenogram of patient at time of admission. Note bilateral pleural effusion and sharply defined capacity extending out from left border of heart. *B*, Lateral chest x-ray view showing the capacity to be in the anterior mediastinum.

Preoperative Course.—The boy was observed seven weeks before surgical exploration. Attention was directed to the generalized fluid accumulation. Two days after admission (March 2, 1946) a paracentesis was performed yielding 4,200 c.c. of bright orange-yellow fluid with a specific gravity of 1,016. Total protein determination gave a value of 3.20 Gm. per cent. Tests for bile were negative. Microscopically, red blood cells were seen. Nothing grew on culture of the fluid.

Three days later (March 5, 1946) a paracentesis yielded 700 c.c. of bloody fluid with a specific gravity of 1.010, total protein 1.08 Gm. per cent, albumin .55 Gm. per cent, globulin .53 Gm. per cent, and nonprotein nitrogen 22 mg. per cent. The patient had decreased in weight from 69.4 to 60.8 kilograms in this one week of preoperative preparation.

Operation.—The anesthesia was ethylene-oxygen plus ether under positive pressure. High oxygen concentration was necessary throughout the procedure.

An incision was made encircling the lower aspect of the left breast, and the left pleural cavity was entered through the left fifth interspace after division of the fourth and fifth costal cartilages. Considerable pleural fluid escaped as the cavity was opened. The left lung was found to be very firmly fixed to the heart and mediastinum anteroinferiorly and both visceral and parietal pleura in the region were markedly thickened. A firm tumor mass approximately 2 to 2½ inches in diameter was found located in the anterior mediastinum directly over the pulmonary conus. It was bound down firmly with dense adhesions due to thickening of the mediastinal pleura.

considered a rare cause of constrictive pericarditis although it is responsible for most asymptomatic adhesive pericardiums and mediastinopericarditis. (White,[10] Harrison and White,[20] Sprague and co-workers,[21] Sellors,[13] and others.)

With few exceptions the remaining cases are classified as idiopathic. All but one of our eight cases fell into this category. It was said by Trout[22] that the problem in establishing the etiology in this group is due to the fact that an organism causing a prolonged defensive process would be difficult to find late in the disease. Some authors feel that these are unproved cases of tuberculosis. Wells[23] postulated a spread of sclerogenic products of tubercle bacilli to pericardial and pleural surfaces from adjacent tuberculous lymph nodes. Due to lack of evidence, the etiology in a large proportion of cases remains undetermined.

The following case is being reported because of an unusual basis for unsuccessful surgical therapy. The pulmonary veins were markedly stenosed by fibrous tissue. This unique phase of the process was not disclosed until autopsy.

CASE REPORT

A white boy, (No. 376848), aged 14 years, was seen for the first time at the University of Chicago Clinics on Feb. 27, 1946. Complaints were swelling of the abdomen for five to six weeks, dyspnea for four weeks, and ankle swelling for several days. Past history revealed an episode of severe dyspnea three years previously which subsided in three days. A chest roentgenogram at that time by a local physician showed a marked semicircular bulge on the left heart border in the region of the pulmonary conus. He was asymptomatic until October, 1945, when he was admitted to a contagious disease hospital for a short period with a questionable diagnosis of meningitis. In January, 1946, he developed a respiratory infection from which he recovered in two weeks. Two weeks subsequently, however, he noticed an abdominal enlargement. Paracentesis yielded four quarts of straw colored transudate from which nothing was cultured. In the remaining three weeks before admission to the hospital he required two more paracenteses.

This boy had had the common childhood illnesses and had not had rheumatic fever. The family history was noncontributory.

Physical examination revealed a well-developed, but not too well-nourished, boy. There was bilateral pleural effusion and râles at the left base. The respiratory rate was 24 per minute. The heart was enlarged to percussion. On auscultation the heart sounds were distant and indistinct. No friction rub nor murmurs were heard. The heart rate was 130 and there was a definite pulsus paradoxus. The blood pressure was 112/88. The abdomen was very distended and tense, and a fluid wave was present. No organs were palpable, but the liver was percussible two fingers below the costal margin. There was 1 plus edema of the ankles.

Laboratory.—Blood examination revealed a red blood cell count of 5.29 million, hemoglobin 15 Gm., hematocrit 48, and white blood cell count 7,050. The differential count was 62 per cent polymorphonuclears, 34 per cent lymphocytes, 3 per cent monocytes, and 1 per cent eosinophiles. Wassermann, Kahn, Mantoux in 1:1000 concentration, and the tuberculin patch test were all negative. The sedimentation rate was 5 mm. per hour (Wintrobe). Blood chemistry values were: nonprotein nitrogen 22 mg. per cent, plasma proteins 6.5 Gm. per cent, albumin 3.14 Gm. per cent, globulin 3.29 Gm. per cent, albumin-globulin ratio of .95; serum cholesterol 136 mg. per cent, and alkaline phosphatase 8.6 units. The urine was normal.

X-ray views of the chest showed bilateral pleural effusion and a large rounded mediastinal mass on the left side. The heart was enlarged. Aneurysm of the aorta or pulmonary artery

Operation.—The operation was performed on April 4, 1946. The incision extended from the left third costal cartilage, downward over the left border of the sternum, and outward over the sixth costal cartilage. The pectoralis major muscle was reflected laterally and the fourth, fifth, and sixth costal cartilages were removed subperichondrially along with a short stump of the anterior ends of the fourth and fifth ribs. The left pleura and lung were then dissected laterally from over the perichondrium after ligation of the left internal mammary vessels at the upper and lower end of the exposed area.

The pericardium was definitely thickened and very little cardiac movement could be seen. On opening the pericardium, hemorrhagic transudate spurted out under high pressure. The incision in the pericardium was enlarged and a large amount of fluid was removed. The anesthetist stated that the color of the patient improved immediately and the blood pressure increased to 130/100. The pericardium was then excised over an area approximately 2½ by 2 inches and a large Penrose drain was placed on the bottom of the pericardial cavity.

Exploration with a finger revealed no adhesions between the pericardium and the heart muscle. The epicardium was somewhat thickened but did not interfere with heart activity. The chest wound was then closed in layers. The Penrose drain was sutured to the skin. During the procedure the patient received 200 c.c. of whole blood and 200 c.c. of normal saline solution.

The thickened pericardium removed at surgery showed perivascular infiltration of chronic inflammatory cells. Nothing was cultured from the fluid. A guinea pig into which the fluid was injected was later sacrificed and found to be normal.

Postoperative Course. The patient made a satisfactory recovery with routine management. The wound healed readily. The cardiorespiratory function improved considerably. With the occasional aid of diuretics, the pleural fluid and ascites markedly decreased and the ankle edema disappeared. The boy felt well and was able to walk about in his room.

On May 3, 1946, a grayish-white membrane on the palate was observed, considered Vincent's angina, and treated as such. One week later the diagnosis of moniliasis was established. The lesions involved the pharynx, nasopharynx, larynx, and trachea by that time. They were treated locally with 2 per cent aqueous gentian violet and systemically with sulfadiazine, 5 Gm., and sodium bicarbonate, 3 Gm. After gross hematuria on May 16, 1946, the systemic therapy was abandoned. The visible lesions disappeared after two weeks of therapy, but therapy was continued for two months.

After May 10 his condition in relation to the primary disease was relatively stationary. Urinary output averaged around 600 c.c. per day except for occasional days when 1 c.c. of Mercupurin was given to induce diuresis. Breathing was difficult at times, but pleural fluid by x-ray and fluoroscopy was decreasing in amount. Some ankle edema and ascites accumulated in mid-June and paracentesis was done June 18. The 4,870 c.c. of clear yellow fluid had a specific gravity of 1.020.

An x-ray on June 27 showed the heart to be relatively normal in size and a small amount of pleural fluid was present (see Fig. 3).

Ascites and ankle edema became evident again on July 10, 1946. There was venous engorgement and the venous pressure was 300 mm. of water.

Mercupurin (1 c.c.) was given to promote a diuresis about once a week and the patient continued to pursue a somewhat static course. Plasma proteins, nonprotein nitrogen, and the venous pressure remained at the previous levels.

Another paracentesis of 3,400 c.c. was done July 29. Despite removal of large quantities of pleural and ascitic fluid the plasma proteins were at no time subnormal. The albumin-globulin ratio, however, was always less than one.

By August the disease process was thought to have entered a chronic phase and further surgery seemed indicated.

Operation.—Aug. 13, 1946, partial pericardectomy was done. An incision was made through the scar of the former operation, the upper and lower angles being extended.

After mobilizing the lung from the pericardium and mediastinal pleura, a cleavage plane was found between the tumor mass and the pericardium, and by blunt and sharp dissection it was gradually freed from these structures. It was firmly attached to the pericardium by dense fibrous adhesions. No large blood vessels were encountered.

As soon as the mass was mobilized the conus showed considerable pulsation, and it was evident that this had been considerably obstructed by the mass. On release of this obstruction, the patient's respiratory rate dropped from 42 to 28, his color improved perceptibly, and the pulse rate as well as quality improved. The mass was completely removed.

The chest wound was closed in layers, a pezzar suction catheter being brought out through a stab wound for drainage.

The patient was given 1,150 c.c. of whole blood and 300 c.c. of normal saline solution while on the operating table.

The mass was a multiloculated cyst about 8 by 6 by 5 cm. with walls varying from 1 to 5 mm. The cyst contained some clots and some reddish brown fluid which, analyzed chemically, gave these values: total protein 5.75 Gm. per cent, albumin 2.75 Gm. per cent, globulin 3.0 Gm. per cent, nonprotein nitrogen 41.3 mg. per cent, sugar 34 mg. per cent, total cholesterol 265 mg. per cent, and free cholesterol 179 mg. per cent (see Fig. 2, *A*). Histologically it consisted of fibrous walls and organizing granulation tissue as a cyst lining. There were hemosiderin deposits and a few lymphocytes and plasma cells scattered throughout the connective tissue. Several large endothelial-lined vascular structures filled with blood elements established the pathologic diagnosis as cavernous hemangioma of the mediastinum (See Fig. 2, *B*).

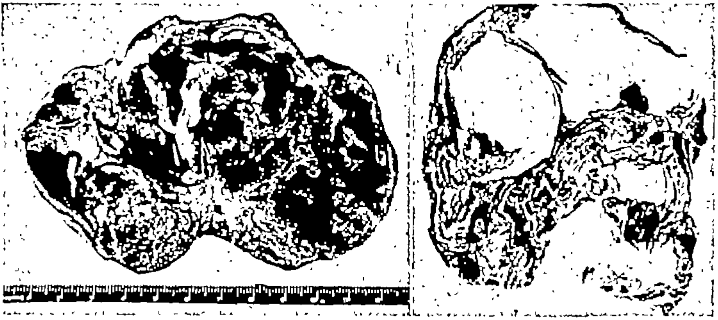

Fig. 2.—*A*, Photograph of opened tumor mass removed from over the pulmonary conus in the anterior mediastinum. Note multiloculation with considerable fibrosis in the trabeculae. *B*, Low-power microscopic section through entire tumor mass. Note spaces of various sizes and shapes partly filled with blood. Some areas of calcification may be seen.

Postoperative Course.—The patient did well following operation and appeared to be improved, but only for a short time. The wound healed by primary intention. Fluid continued to accumulate in the peritoneal and pleural cavities, however, and the venous pressure remained elevated. The left pleural cavity gradually became obliterated. Paracentesis and thoracentesis on the right side of the chest were carried out and diuretics given.

On fluoroscopic examination the cardiac movements were markedly diminished. This finding, along with increased venous pressure, strongly suggested the diagnosis of pericardial effusion or constrictive pericarditis. Aspiration of the pericardial cavity revealed a relatively small amount of bloody fluid. An exploration was thought to be indicated. Plasma proteins at this time were 7 Gm. per cent, albumin 3.1 Gm. per cent, and globulin 4 Gm. per cent.

There was a slight increase in urinary output and on Aug. 19, 1946, the sixth postoperative day, the carbon dioxide capacity of the plasma was 66.8 vol. per cent and the pH was 7.4. Plasma proteins and nonprotein nitrogen were only slightly altered from the values on Aug. 16, 1946. The sedimentation rate, as on every determination throughout the course, was not elevated.

A paracentesis on Aug. 18 yielded 2,950 c.c. On Aug. 22 an x-ray examination of the chest revealed bilateral congestion of the lungs (see Fig. 4).

Respiration became labored on Aug. 20, one week after surgery, and the urinary output was only 200 c.c. per day. On Aug. 22 the boy became cyanotic and respiration was still more difficult. A chest film showed passive congestion and a small amount of pleural fluid. The output that day was only 150 c.c.

At 4 A.M. on Aug. 23 his condition became decidedly worse. He was very cyanotic, respirations were slow, pulse was very weak, and he could not be aroused.

He improved slightly in the early morning with repeated doses of caffeine and sodium benzoate, Coramine, and Digalen. However, respiration became very weak, pulse irregular, and the extremities cold and moist. Râles and rouchi were heard in the chest. He died at 12:40 P.M.

Autopsy.—The body showed emaciation and a dilation of venous collaterals on the trunk. There was chronic polyserositis with generalized edema and chronic passive congestion.

There was obliterative fibrous pleuritis and pericarditis, except for the anterior pericardium which had been surgically removed. The pulmonary veins were very stenosed by rigid fibrous rings where they passed the pleuropericardium. The inferior pulmonary veins would not admit a finger tip and the superior vessels would barely do so. The superior and inferior vena cavae were distended but were not stenosed at any point. The aorta and pulmonary artery were normal.

The heart was distorted in shape due to a definite right ventricular hypertrophy. The valves were all normal.

The lungs demonstrated an extreme degree of chronic passive congestion and had areas of bronchopneumonia and chronic interstitial pneumonitis. A small peribronchial lymph node had an encapsulated (inactive) area of tuberculosis.

There were 2,100 c.c. of ascites. The peritoneal surfaces were irregularly thickened and white. There were many adhesions between the bowel and abdominal organs.

In addition to adhesions, the capsule of the liver was everywhere thickened. An extreme degree of fibrosis in the region of porta hepatis stenosed the portal vein in this area. Distal to the stenosis the intima of the vein was thickened.

The bowel wall was increased in thickness by 50 per cent due to edema and fibrous white thickening of the serosa. The mesentery was short and stiff and there were many adhesions between adjacent loops of the bowel. They tended to form cystlike structures.

The kidneys, pancreas, liver, and spleen all demonstrated chronic passive congestion. The kidneys on microscopic examination had many hyaline and granular casts, and many round bodies lodged in the tubules. This was considered obstructive nephropathy due to sulfa drug.

Histologically, the over-all picture was one of much vascular fibrosis on all serous surfaces with minimal amounts of inflammation.

DISCUSSION

In this case a congenital (cavernous hemangioma) and inflammatory lesion of the mediastinum were coexistent. The effect of the pleuritis and pericarditis on the circulation was enhanced by the congenital lesion compressing the pulmonary conus. The simultaneous action of these two processes was shown by the fact that the left pleural cavity was partially obliterated at the time of surgical removal of the hemangioma and the pathologic specimen demonstrated some chronic inflammation.

The soft structures of the chest wall were reflected to the left from over the pericardium. Parts of the third, fourth, and fifth ribs were removed subperiosteally to allow exposure. The left pleura and lung were then reflected from over the pericardium, and the former opening into the pericardial sac was found to be closed by fibrous tissue.

Further exploration revealed the pericardial sac to be completely obliterated. After rongeuring away a considerable amount of the lower sternum, the pericardium was freed from the heart, first over the left ventricle anteriorly and to the left, and then over the right ventricle anteriorly. Two pieces of pericardium, measuring about 3 by 1½ inches each, were removed. The heart enlarged noticeably as the pericardium was freed from its surface.

The soft structures of the chest wall were then sutured over the heart after placing one Penrose drain in the wound.

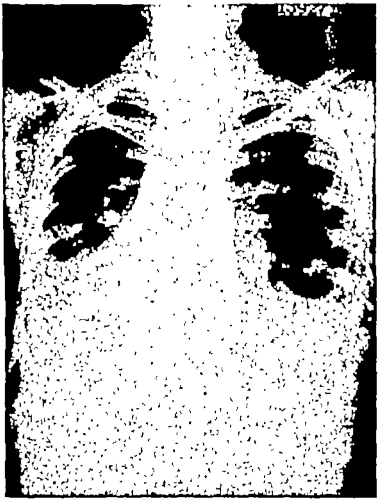

Fig. 3.

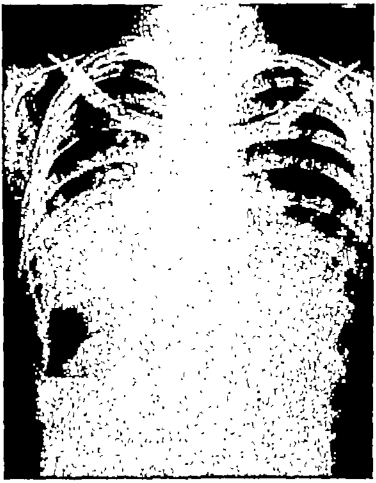

Fig. 4.

Fig. 3.—Chest roentgenogram taken almost four months after removal of mediastinal hemangioma and three months after partial pericardectomy. Note improved aeration of the lungs due to decrease in pleural effusion.

Fig. 4.—Chest x-ray view one day prior to expiration; there is considerable bilateral pulmonary congestion.

Postoperative Course.—The patient received the routine care including penicillin and nasal oxygen. Soon after surgery he was given 300 c.c. of whole blood, the transfusion being terminated because the venous pressure was found to be 375 mm. of water.

On the second postoperative day the temperature was 37°C., pulse rate 110-120, and respiratory rate 30 per minute. Blood pressure was 100/65. The hemoglobin was 10.5 Gm. and white blood cell count 5,000. The urinary output after surgery was only 300 c.c. per day.

Blood chemistry on the third postoperative day revealed a slight alkalosis; the carbon dioxide capacity was 75 vol. per cent, pH 7.45, and chlorides 85 mM/1. Plasma proteins were 6.62 Gm. per cent, albumin 3.10 Gm. per cent, globulin 3.45 Gm. per cent, albumin-globulin .93, and nonprotein nitrogen 52.6 mg. per cent. Ammonium chloride, 3 Gm., was started and the following day the patient received 300 c.c. of whole blood and 60 c.c. of normal saline intravenously.

Six of the patients were sufficiently improved to carry on normal life activities. Of these, two required a second pericardial resection to attain this result. Complete recovery in two of this group was not achieved until digitalization was carried out.

In addition to the case reported in this paper there was one other death. This occurred in the patient of 47 years who had active tuberculosis as the cause of chronic pericarditis. There was no clinical improvement after surgery and the patient died seven months later. Post-mortem examination was not performed.

There was evidence of great vessel involvement only in the case which is the subject of this report. We consider the severe constriction of the pulmonary veins the basis for failure of surgical therapy in this patient.

SUMMARY

A case of constrictive pericarditis is presented in which the patient was studied from the onset of the process to its fatal termination. Surgical therapy was ineffective due to a unique process not disclosed until autopsy, namely, severe stenosis of the pulmonary veins by fibrosis in the pleura and pericardium. Decortication of the heart ordinarily yields a high percentage of cures in these patients as demonstrated by the results in seven additional cases.

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After the congenital lesions was removed there was temporary improvement in the patient's condition. However, progression of the inflammatory process and accumulation of pericardial fluid required further surgical intervention. Drainage of pericardial fluid at the second operation again led to marked improvement which was of several months' duration. This was terminated by the steady increase in constriction produced by the process in the pericardium. Surgical decortication of the compressed heart allowed the heart to increase diastolic filling. The pulmonary vein constriction impaired the pulmonary circulation to such an extent, however, that improvement did not take place. One week after surgery the patient began a rapid downhill course, terminating a few days later.

In the typical case of constrictive pericarditis the fibrous scar firmly encases the heart and there is no cardiac enlargement. Sellors[13] said that the pulmonary circulation, in contrast to the systemic, is relatively unaffected in this condition because a small volume is pumped into it. The right ventricle in this patient was greatly hypertrophied, however, and this was probably due to mechanical stress placed on the pulmonary circulation. This can be attributed to (1) the tumor compressing the pulmonary conus, and (2) the constriction of the pulmonary veins. The latter was of such severity that release of the heart from its constricting pericardium was not sufficient for recovery of normal circulatory mechanism.

In a search through the literature on constrictive pericarditis we have been unable to find a case of pulmonary vein constriction proved by post-mortem examination. There are many cases reported in which it has been proved that the fibrous process had involved the superior and/or the inferior vena cava. Gouley[24] reported six cases of chronic mediastinopericarditis with pulmonary artery constriction proved by post-mortem examination. Egan[25] in a pathologic report described constriction of the pulmonary vein orifices by calcium rings. This, however, was in a case of calcium deposition in the cardiac musculature.

At post-mortem there was an extensive fibrous peritonitis. The portal veins was markedly compressed by fibrous adhesions at the porta hepatis. Rolleston[16] said this occurrence was very rare even when the portal fissure was involved by perihepatitis. White[26] also said that this must be very rare because jaundice was so rare in these cases. He assumed that simultaneous constriction of the common bile duct must occur.

There was an unusual opportunity in this case to study the development of constrictive pericarditis from the onset of the process. Before many changes had occurred in the pericardium, symptoms brought the patient to the clinic. Probably the additional effect of the congenital lesion was instrumental in this respect.

RESULTS IN ADDITIONAL CASES

At the University of Chicago Clinics seven additional patients with constrictive pericarditis had surgical decortication of the heart. They ranged in age from 14 to 31 years, except for one man of 47 years. Etiology could only be determined in one patient and this was tuberculosis.

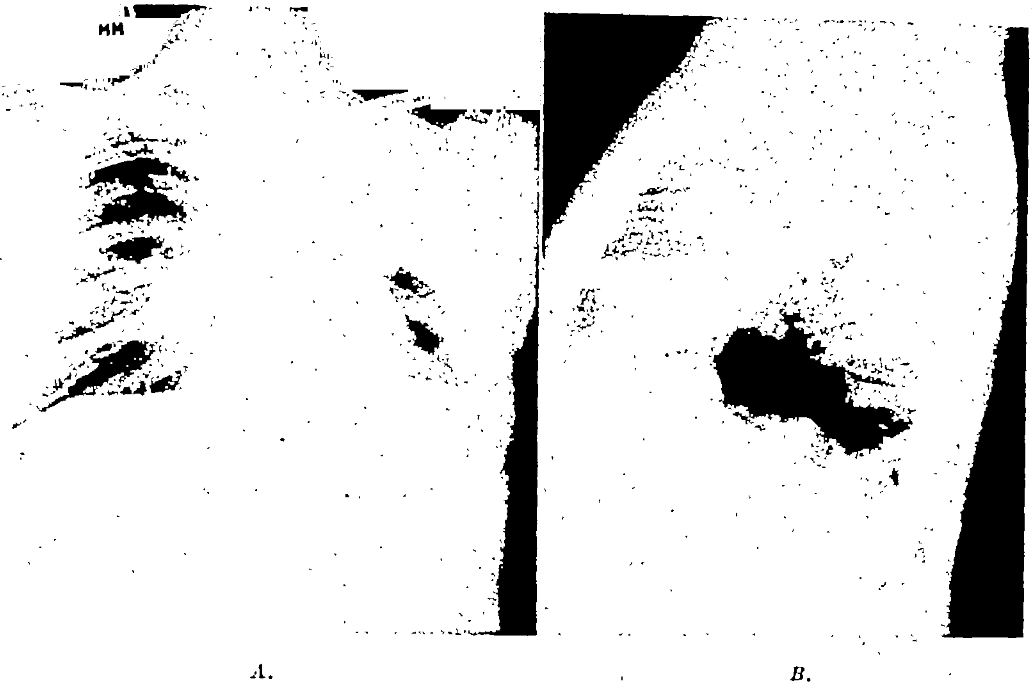

Fig. 1.—*A* and *B*, Roentgenograms show density in upper half of left lung field.

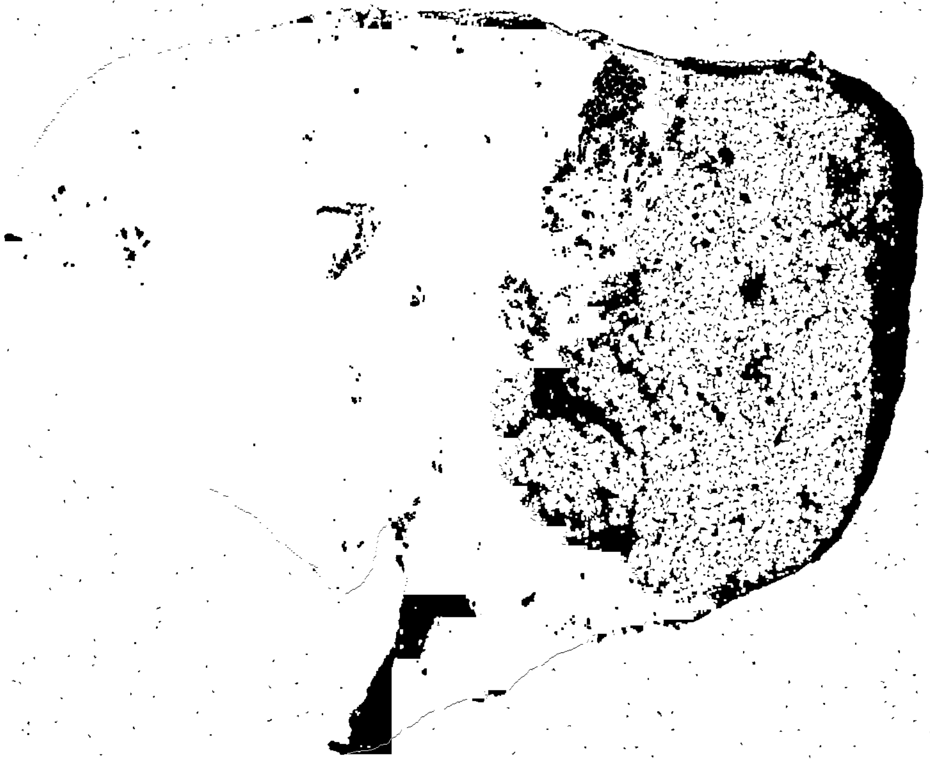

Fig. 2.—Cut section of left lung. Tumor is lighter in color than normal lung. Note how well the bronchi are preserved and stand out on the cut surface.

PRIMARY LYMPHOSARCOMA OF LUNG

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PULMONARY lesions are common in lymphomatoid diseases, but the literature contains very few reports of primary lymphosarcoma of the lung. In an analysis of 196 cases of lymphosarcoma proved by biopsy, Sugarbaker and Craver[1] found that the lung was the apparent primary site of lymphosarcoma in only one instance, or 0.5 per cent of the cases. A case is herewith reported in which a large lymphosarcoma involving about one-half of the left lung was removed by pneumonectomy. The patient was in excellent general condition and free of evidence of disease for over one and one-half years following operation. Then roentgenograms revealed a small lesion in the other lung which was successfully treated by radiation therapy. Three years have now elapsed since the pneumonectomy and the patient appears to be well at this time.

CASE REPORT

M. M., was a man aged 50 years. Three months prior to admission the patient was examined because of a slight exacerbation of symptoms caused by a chronic gastric ulcer. On fluoroscopic examination a lesion was discovered in the left lung. The patient had no pulmonary symptoms. There was no cough, chest pain, hemoptysis, dyspnea, or loss of weight. On physical examination the patient appeared well developed and somewhat obese. He did not appear ill. There was no evidence of lymphadenopathy. The positive findings on physical examination were dullness over the upper half of the left lung field anteriorly and over the upper third posteriorly. Bronchial breath sounds were present over the same area. There were occasional crepitant râles at the end of inspiration. The remainder of the left lung field and the entire right lung field were clear. A roentgenogram of the chest showed asymmetry of the thorax with narrowing of the interspaces on the left side. The left leaf of the diaphragm was elevated but not paralyzed. The heart and mediastinal structures were slightly displaced to the left. The area of the left upper lobe was uniformly dense (Fig. 1). A bronchoscopy showed no evidence of an endobronchial lesion, and no distortion or fixation of the tracheobronchial tree. Exploratory thoracotomy was recommended. The diagnosis was in doubt. Because of the large size of the tumor mass and the complete absence of pulmonary symptoms, a bronchiogenic carcinoma, although still a definite possibility, did not seem likely. On Oct. 23, 1944, an operation was performed and the findings were as follows.

The left upper lobe was diffusely adherent to the chest wall by adhesions which were moderately vascular but readily divided. The entire upper lobe was dense, but did not have the firm consistency usually found with carcinoma. The surface of the upper lobe was gray in color. The lower lobe was air-containing. The main bronchus showed no abnormality at the site of section. The mediastinal and bronchial lymph nodes were not enlarged. A hilar dissection type of total left pneumonectomy was performed. The postoperative course was uneventful.

Pathologic examination of the lung revealed almost the entire upper lobe to be replaced by a tumor mass of relatively soft consistency. The lower lobe was aerated and appeared relatively normal. On cut section the upper lobe was occupied by a tumor which was

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pale gray in color and which thickened the lung tissue uniformly without causing it to lose all of its elasticity. All the bronchi were preserved and stood out on the cut surface of the lung (Fig. 2). The tumor crossed the interlobar septum, obliterating it, and invaded the lower lobe for a short distance. The remainder of the lower lobe seemed normal. The pleura was thickened where the tumor came in contact with it, but there was no extension of the tumor through the pleura. The main bronchi were free of tumor.

On microscopic examination the lung was extensively infiltrated by a tumor composed largely of lymphoblasts mixed in places with an occasional reticulum cell (Fig. 3). The pulmonary substance had been largely replaced not only by the infiltrative growth but by an extensive process of fibrosis. Mitoses were rare and relatively difficult to find. The lesion appeared to be a solitary and apparently primary lymphosarcoma of the lung which must have grown slowly and in a relatively restrained fashion, since there was a good deal of associated fibrosis. There was no evidence of lymph node involvement.

The patient continued to be asymptomatic and remained in excellent health. Roentgenograms of the chest were taken at suitable intervals. In May, 1946, nineteen months after operation, a small area of density was noted in the outer portion of the right midlung field. The lesion increased in size very slowly during the following seven months. The patient remained completely asymptomatic. In December, 1946, radiotherapy was instituted.* A total of 1,150 r was given to each of two fields over the right side of the chest with almost complete disappearance of the lesion on the roentgenogram. In July, 1947, only a linear density remained on the film. The patient has gained ten pounds during the past three years. There has never been any evidence of lymphadenopathy.

All types of primary sarcoma of the lung are rare. In past years small round-cell or oat-cell carcinoma of the lung has been confused with sarcoma. The gross and microscopic appearance of the tumor described here differs from the small-cell carcinoma. Lymphosarcoma arising in the lung has been considered to be so unusual that its existence has even been doubted by some pathologists. In contrast, however, is the frequent occurrence of involvement of the lung secondary to lymphosarcoma of the bronchial and mediastinal lymph nodes. Vieta and Craver[2] analyzed 239 cases of lymphosarcoma in which roentgen studies of the lungs were made. Infiltration of the lung occurred in 23.8 per cent. The parenchymal infiltrations as shown on the roentgenogram were usually diffuse, but in 5.8 per cent isolated nodular masses occurred. In many instances the infiltration appeared to effect the greater portion of the lobe of the lung by direct extension from the hilar structures. Formation of discrete, lobular foci was nearly always accompanied by infiltrative lesions.

Churchill[3] recently reported a case of primary lymphosarcoma of the lung successfully treated by lobectomy. This 45-year-old woman complained of bouts of fever and generalized malaise. She had experienced vague pains in the right thoracic region for many years. The roentgenogram showed a large dense area in the right upper lobe which did not correspond with a bronchopulmonary segmental distribution. There was a slight reduction in the volume of the diseased portion of the lung. The lymph nodes were apparently uninvolved. The patient was given radiation therapy postoperatively and was well six months later.

Spatt and Grayzel[4] reported a case of primary lymphosarcoma of the lung which was also successfully treated by lobectomy. Their patient was a 34-year-old woman who complained of moderate cough and bloody sputum. Roentgenograms showed a small egg-shaped mass in the right lower lobe. The surgical

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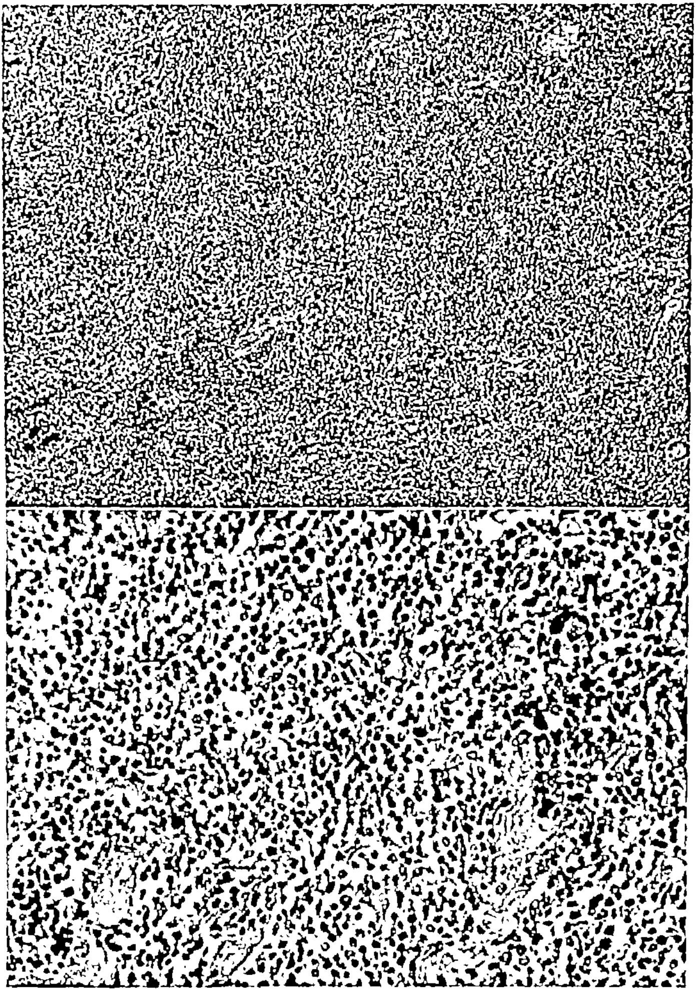
*By Dr. Maurice Lenz.

A.



B.

Fig. 1.—*A* and *B*, Photomicrographs of tumor; note the uniform appearance of the lymphoblasts.

COMPLETE DISRUPTION OF THE ESOPHAGUS

Report of Case

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IT IS interesting to note that the earliest recorded case of rupture of the esophagus was one of complete disruption. Zenker and von Ziemssen[1] quoted Boerhaave's[2] description in 1724 of the necropsy on Admiral Baron Wassenaer, wherein Boerhaave mentioned the "esophagus, whose continuity had been sundered, and the two portions had been dragged respectively upward and downward."

Barrett,[3] writing in March, 1946, stated that more than fifty cases of spontaneous rupture of the esophagus had been recorded since Boerhaave's case and that in none of these cases had treatment been successful. In August, 1946, Eliason and Welty[4] made a similar observation qualified by mention of two cases of Graham in which the rupture resulted in empyema and the patient recovered after drainage of the empyema.

Walker[5] in 1914 suggested that, if diagnosis was made early, the patient might be saved by posterior mediastinotomy, the rent being repaired and the mediastinum and pleural cavity drained. Shock and sepsis made him think success would be unlikely, but in the past one and one-half years much has been accomplished by surgical attack along these lines. A complete study of the subject, with report of five cases, in one of which the patient underwent operation but died nine days postoperatively of a pulmonary embolism, will soon be published by Kinsella, Morse, and Hertzog.[6]

Also, one of us (T.O.C.) has recently performed repair successfully in one case of this so-called spontaneous rupture of the esophagus.

Much speculation has gone on concerning the status of the esophagus prior to "spontaneous" rupture. It is thought that despite the lack of ulcer, stricture, neoplasm, or other visible lesion the esophageal wall cannot be healthy if it becomes the site of a rupture. Zenker and von Ziemssen explained this by esophagomalacia—a weakness inherent in the tissues. The case reported here is not one of those in which rupture occurs in an otherwise normal esophagus. Our patient had a congenitally short esophagus type of hiatal hernia, which almost always has associated with it a stricture at the esophagogastric junction.

That esophageal strictures predispose to, or at least often precede, rupture of the esophagus is suggested by the reports of Vinson,[9] Smead,[7] Weder,[8] and others, who, however, described lye strictures,[9, 10] usually 3 to 5 inches (8 to 13 cm.) above the cardia. In these cases, rupture occurred between strictures and cardia owing to the unrelieved or slowly relieved pressure of vomiting.

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specimen revealed a moderate-sized bronchus extending into the mass and fusing with it. Small bronchiectatic cavities were also present. Microscopic examination revealed the tumor cells to be particularly prominent about the bronchi and bronchioles and to a lesser degree about the blood vessels. The patient was well fourteen months after operation.

In most cases of lymphosarcoma the involvement is too diffuse to permit complete surgical removal of the diseased tissue, and radiation therapy is the treatment of choice. When the process is sufficiently localized, radical surgical excision, perhaps combined with radiation therapy, may give the best results. Lymphosarcoma usually involves the lung secondarily, but when the pulmonary lesion is apparently primary, lobectomy or pneumonectomy may be indicated. No conclusions as to the relative merits of surgery and radiation therapy in the treatment of primary lymphosarcoma of the lung can be drawn from my case. Since the lesion which later appeared in the right lung responded well to radiation therapy, it is quite possible that a favorable result might also have been obtained if the original large lesion in the left lung had been irradiated. A positive diagnosis of primary lymphosarcoma would be difficult to establish, however, unless an exploratory thoracotomy were performed.

SUMMARY

A case of a large, apparently primary lymphosarcoma of the lung treated by pneumonectomy is reported. A small lesion which later appeared in the opposite lung responded well to radiation therapy. The patient never had any pulmonary or other symptoms referable to the lymphosarcoma, and is clinically well over three years after pneumonectomy. Two previously reported surgically treated cases of primary lymphosarcoma of the lung without mediastinal lymph node involvement are briefly reviewed.

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the finding of multiple parathyroid adenomas. An incidental finding was a small islet-cell carcinoma of the pancreas which had metastasized to the duodenum and to the peripancreatic and choledochal lymph nodes.

COMMENT

Several interesting possibilities arise in one's mind concerning the cause of, or the predisposing factors in, this disruption of the esophagus from the stomach.

Certainly it seems, first of all, that a congenitally short esophagus type of diaphragmatic hernia, with its well-known concomitant stricture at the esophagogastric junction, would definitely predispose mechanically toward such a catastrophe. If, in addition, the disturbance of calcium metabolism and the presence of a carcinoma with metastasis (asymptomatic) lent a systemic effect deleterious to strength and elasticity of tissue it seems easy to understand how an attack of violent vomiting was all that was needed to effect the disruption.

The fact that this was a *total disruption* seems best explained on the basis of the pre-existing lesion. The stricture almost always accompanying congenitally short esophagus is of the complete circumference of the esophagogastric junction. However, there are many patients encountered with such lesions, and undoubtedly many of them occasionally vomit; yet there is no known previous instance of disruption among this group as far as we can determine, although rupture of the esophagus occurs fairly often in patients with strictures from other causes.

In the case reported here the prognosis was completely hopeless. The duration of the rupture was probably twelve to fifteen hours and the general condition of the patient, the local status of the mediastinal tissues and ends of the esophagus and stomach, and the presence of bilateral hydropneumothorax all combined to preclude any possibility of operation.

Had the diagnosis been made earlier it is conceivable that an anastomosis might have been possible, the necrotic ends of the two separated viscera being resected if necessary. Early diagnosis, however, requires early consideration of the possibility of rupture of the esophagus, and as yet this fortunately rare catastrophe is not commonly borne in mind.

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The present case is unusual in several respects, but mainly because this is a case of total or complete disruption, occurring at the site of stricture.

REPORT OF CASE

The patient was a widow, aged 54 years, who had had no previous illness except typhoid fever in 1897. She was referred to the Mayo Clinic by her local physician, who had noted albuminuria and pyuria for the previous eight months and had made a presumptive diagnosis of a ureteral stone. She had had no renal colic, hematuria, or chills and fever. She had lost from eight to ten pounds (3.6 to 4.5 kilograms). She complained, in addition, of some pain and soreness of the left foot which she had felt for the previous three to four months.

Physical examination showed a small woman walking with a painful limp of the left lower extremity. There were no masses or tenderness in the abdomen. However, there was questionable tenderness in the left costovertebral angle. The arch of the left foot was tender. Laboratory examinations revealed albuminuria, grade 3 (on the basis of 1 to 4, in which 1 designates the mildest and 4 the most severe condition), and pyuria, grade 1. Roentgenograms of the left foot showed osteoporosis and a fracture of the left third metatarsal bone. Roentgenograms of the thorax showed slight osteoporosis of the ribs. Investigation of the kidneys, ureters, and bladder revealed a stone in the lower part of the right ureter and operation was advised. Hyperparathyroidism was considered to be likely but not to contraindicate operation.

On July 28, 1947, one of the urologic surgeons explored the right ureter and removed a stone from the intramural portion of the ureter. Before operation the patient had vomited slightly but had had no other gastrointestinal symptoms. During operation, which was done while she was under spinal anesthesia, she vomited rather violently but this was not considered unusual in view of the anesthesia. Early the following morning, July 29, 1947, the patient vomited again. This time there was old blood in the vomitus. In addition, difficulty in breathing began to develop. As it was thought that there had been aspiration of some of the vomitus, an attempt was made to aspirate the stomach. However, the tube could not be introduced into the stomach. A roentgenogram of the thorax revealed mediastinal emphysema and an aberrant position of the end of the stomach tube, apparently not in the esophagus and certainly not in the stomach. The patient was seen by one of the consultants on diseases of the thorax, who noted subcutaneous emphysema of the thoracic wall and neck. These findings, together with the roentgenographic appearance of the thorax and the degree of shock in which she was, led to the probable diagnosis of rupture of the esophagus and mediastinitis. The possibility of a previous asymptomatic esophageal hiatal hernia or of an epiphrenic diverticulum was entertained.

When we saw the patient it was felt that further diagnostic studies would be both impossible and wasteful of time in view of her condition, and accordingly, exploration of the inferoposterior mediastinum was done through a vertical incision parallel to the lateral edge of the left sacrospinalis muscle at the level of the eighth and ninth ribs. Posterior segments of these ribs were resected as well as the intervening intercostal muscle bundle. Extrapleural dissection into the posterior mediastinum revealed discolored, edematous, gangrenous tissues and with final exposure of the esophagus and stomach, there was revealed a complete disruption of the esophagus from the stomach. Approximately 2 to 3 inches (5 to 8 cm.) of the stomach was in the thorax (congenitally short esophagus type of hiatal hernia). The two vagus nerves were the only connections remaining between the esophagus and the stomach. The ends of these latter two viscera were inflamed, friable, and necrotic. In addition, there were openings into both pleural spaces which made the maintenance of anesthesia and respiration extremely difficult. It was impossible to consider an anastomosis of the esophagus to the stomach, and the patient was returned to her room, where she died approximately twelve hours later.

Post-mortem examination confirmed the operative findings described in the preceding paragraph and in addition confirmed the preoperative suspicion of hyperparathyroidism by

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Bean, D. M. (with Kergin, F. G., and Paul, W.). Anoxia during intrathoracic operations, 709

Beck, Claude S. Discussion of controlled breathing in transpleural operations, 295
  (with Mautz, Frederick R., and Chase, Harold F.). Augmented and controlled breathing in transpleural operations, 283

Bettman, Ralph B. Discussion of nonspecific suppurative pneumonitis, 512
  Discussion of pulmonary resection for lung abscesses, 534

Betts, Reeve H. (with Overholt, Richard H., and Woods, Francis M.). An improved method of resection of pulmonary segments, 464

Bisgard, Dewey. Discussion of arteriovenous fistula of lung, 25

Blades, Brian (with Effler, Donald B.). Surgical treatment of solitary lung metastasis, 27

Boche, Robert D. (with Gibbon, Mary H., Bruner, H. D., and Lockwood, John S.). Studies on experimental phosgene poisoning, 264

Boerema, I. (with Brilman, R. P.). Cavernous angioma of right lung, 705

Boyden, E. A. (with Scannell, J. G.). Study of variations of bronchopulmonary segments of right upper lobe, 232

Bradford, Martin L. (with Grow, John B., and Mahon, Hugh W.). Exploratory thoracotomy in management of intrathoracic disease, 480

Bradshaw, H. H. Discussion, 218
  (with O'Neill, J. F., and Hightower, Felda). Resection of coarctation of aorta with subclavian aortic anastomosis, 210

Brantigan, Otto C. Discussion of pulmonary resection for lung abscesses, 535
  (with Aycock, T. B.). Self-retaining scapula retractor for thoracoplasty, 390

Brasher, C. A. (with Fujikawa, Y. F., Neves, A., and Buckingham, W. W.). Epidural anesthesia in thoracic surgery, 123

Breathing in transpleural operations, augmented and controlled (Mautz, Beck, and Chase), 283

Brewer, Lyman A., III. Discussion of nonmalignant intrathoracic lesions simulating bronchiogenic carcinoma, 463
  (with Jones, Wilfred M. G., and Dolley, Frank S.) Nonmalignant intrathoracic lesions simulating bronchiogenic carcinoma, 439

Brilman, R. P. (with Boerema, I.). Cavernous angioma of right lung, 705

Bronchi and trachea, regeneration of defects of, an experimental study (Daniel), 335

Bronchial occlusion for prevention of transbronchial spread during lobectomy and pneumonectomy: Clinical application, method of (Moody), 681

Bronchiectasis in service personnel (Laird), 57

Bronchiogenic carcinoma, diagnosis and operability of (Gibbon, Clerf, Herbut, and DeTuerk), 419
  nonmalignant intrathoracic lesions simulating (Brewer, Jones, and Dolley), 439
  with Methyl-bis, treatment of inoperable (Skinner, Carr, and Denman), 428

Bronchopulmonary moniliasis, localized, successfully treated by surgery, report of a case of (Hurwitz and Yesner), 826
  segments of right upper lobe, a study of variations of (Scannell and Boyden), 232

Bronchoscopic and esophagoscopic cinematography (Holinger, Anison, and Johnston), 178

Bronchospirography: apparatus and technique (Norris, Long, and Oppenheimer), 357

Bronchus, myoblastoma of (Kraus, Melnick, and Weinberg), 382

Brown, A. Lincoln. Discussion on nonmalignant intrathoracic lesions simulating bronchiogenic carcinoma, 463

Bruner, H. D. (with Gibbon, Mary H., Boche, Robert D., and Lockwood, John S.). Studies on experimental phosgene poisoning, 264

Buckingham, W. W. (with Fujikawa, Y. F., Neves, A., and Brasher, C. A.). Epidural anesthesia in thoracic surgery, 123

Bunin, Joseph J. (with Maier, Herbert C., Himmelstein, Aaron, and Riley, Richard L.). Arteriovenous fistula of lung, 13

Burch, John C. (with Johnson, Hollis E., Bayer, D. Scott, and McClellan, G. Sidney). Tuberculosis and pregnancy—analysis of one hundred eighteen cases, 636

Byron, Francis R. X. Discussion of arteriovenous fistula of lung, 25
  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 176
  Ectopia cordis—report of case with attempted operative correction, 717

C

Campbell, George W. (with Weinberg, Joseph A., and Voelker, Robert B.). Vagus nerve section in treatment of peptic ulcer—abdominal versus thoracic approach, 743

INDEX TO VOLUME 17

A

Abbott, Osler. Discussion of arteriovenous fistula of lung, 25
  Discussion of dorsal sympathetic ganglionectomy for intractable asthma, 1
  Discussion of exploratory thoracotomy in intrathoracic disease, 493
  Discussion of Methyl-bis for bronchiogenic carcinoma, 438
Abscess of lung, chronic, pulmonary resection *for (Shaw and Paulson), 514*
Abscesses, chronic lung, pulmonary resection for (Kent and Ashburn), 523
Adams, Herbert D. Diverticula of thoracic esophagus, 639
Adams, Ralph. Carcinoma of lung—factors affecting survival after resection of cancer of lung, 306
  Discussion of dorsal sympathetic ganglionectomy for intractable asthma, 1
  Discussion of resection of pulmonary segments, 477
  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 171
Adams, W. E. Discussion of esophageal hiatal hernias of short esophagus type, 200
  Discussion of nonspecific suppurative pneumonitis, 513
  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 174
  (with Kershner, Richard D.). Chronic nonspecific suppurative pneumonitis, 495
  (with Lawrence, Walter, and Cassels, Donald E.). Constrictive pericarditis with obstruction of pulmonary veins, 832
American Association for Thoracic Surgery:
  Board of Thoracic Surgery, 849
  list of members, 136, 850
    officers, 135, 566, 849
  notice, 29th annual meeting, 722, 856
  program, 28th annual meeting, 280
  report of 28th annual meeting, 566
Anastomosis for pulmonary stenosis, aortic-pulmonary (Potts), 223
  subclavian-aortic, resection of coarctation of aorta with (Bradshaw, O'Neill, and Hightower), 210
Anesthesia in thoracic surgery, combined nitrous oxide, pentothal sodium (Hudson and Mackersie), 792
  epidural (Fujikawa, Neves, Brasher, and Buckingham), 123
Angiographic study of form and function of remaining lung after pneumonectomy (Neuhof and Nabatoff), 799
Angioma of right lung, cavernous (Boerema and Brilman), 705
Anison, George C. (with Holinger, Paul H., *and Johnston, Kenneth C.)*, Bronchoscopic and esophagoscopic cinematography, 178
Anomalous pulmonary vessels (Douglass), 712
Anoxia during intrathoracic operations (Kergin, Bean, and Paul), 709
Aorta with subclavian-aortic anastomosis, resection of coarctation of (Bradshaw, O'Neill, and Hightower), 210
Aortic-pulmonary anastomosis for pulmonary stenosis (Potts), 223
Arteriovenous fistula of lung (Maier, Himmelstein, Riley, and Bunin), 13
Ashburn, Frank S. (with Kent, Edward M.). Pulmonary resection for chronic lung abscesses, 523
Asthma, intractable, dorsal sympathetic ganglionectomy for (Carr and Chandler), 1
Atwell, Susanna (with Ehler, Adrian A.). Gastric cyst of mediastinum, 809
Aufses, Arthur H. (with Neuhof, Harold). Cancer of lung—interval and late results of operation in relation to topography and gross pathology, 297
Avery, Edward E. Discussion of Methyl-bis for bronchiogenic carcinoma, 438
  Discussion of symposium on cancer of lung, 321
Aycock, T. B. (with Brantigan, O. C.). Self-retaining scapula retractor for thoracoplasty, 390

B

Baarsma, P. R. (with Dirken, M. N. J.). Collateral ventilation, 238
  (with Dirken, M. N. J., and Huizinga, Eelco). Collateral ventilation in man, 252
Barkley, Howard T. Discussion of resection of coarctation of aorta, 221
Bayer, D. Scott (with Johnson, Hollis E., Burch, John C., and McClellan, G. Sidney). Tuberculosis and pregnancy—analysis of one hundred eighteen cases, 636

Phosgene poisoning, experimental, studies on (Gibbon, Bruner, Boche, and Lockwood), 264
Pleural symphysis, use of oxidized cellulose in (Murphy and McDaniel), 416
Plombage, lucite, extrapleural pneumonolysis with (Wilson), 111
Pneumonectomy, angiographic study of form and function of remaining lung after (Neuhof and Nabatoff), 799
Pneumonitis, chronic nonspecific suppurative (Kershner and Adams), 495
Pneumonolysis, closed intrapleural (Day, Chapman, and O'Brien), 537
  for cure of tension pneumothorax (Cutler), 374
  extrapleural, with lucite plombage (Wilson), 111
Pneumopyopericardium (Meyer), 62
Pneumothorax, extrapleural—late follow-up of eighty-two patients upon whom ninety-two operations were performed (Sullivan), 38
  tension, pneumonolysis for cure of (Cutler), 374
Poppe, J. Karl. Discussion of pulmonary resection for lung abscesses, 535
Potts, Willis J. Aortic-pulmonary anastomosis for pulmonary stenosis, 223, 231
Pregnancy, tuberculosis and (Johnson, Burch, Bayer, and McClellan), 646
Primary rib tumors, survey of literature and report of seven additional cases (Dorner and Marcy), 690
Pulmonary abscesses, acute and chronic, medical treatment of (Smith), 72
  cavities, localization of, by modified roentgenographic technique (Gordon), 274
  inflation and deflation, effect of upon circulation (Thompson), 323
  malignancy, primary (Ochsner, DeBakey, Dunlap, and Richman), 573
  resection for chronic abscess of lung (Shaw and Paulson), 514
    lung abscesses (Kent and Ashburn), 523
  segments, improved method of resection of (Overholt, Woods, and Betts), 464
  stenosis, aortic-pulmonary anastomosis for (Potts), 223
  veins, constrictive pericarditis with obstruction (Lawrence, Adams, and Cassels), 832
    in dog, experimental study of effect of ligation of (Swan and Mulligan), 44
  vessels, anomalous (Douglass), 712

R

Raine, Forrester (with Jennison, David B.). Thoracic casualties from an island campaign in the Pacific, 91
Resection of coarctation of aorta with subclavian aortic anastomosis (Bradshaw, O'Neill, and Hightower), 210
  pulmonary segments, improved method of (Overholt, Woods and Betts), 464
Rib, eosinophilic granuloma of (Maurer and DeStefano), 350
  tumors, primary—survey of literature and report of seven additional cases (Dorner and Marcy), 690
Richman, Irving (with Ochsner, Alton, DeBakey, Michael, and Dunlap, Charles E.). Primary pulmonary malignancy—factors influencing survival, 573
Riley, Richard L. (with Maier, Herbert C., Himmelstein, Aaron, and Bunin, Joseph J.). Arteriovenous fistula of lung, 13
Roentgenographic technique, modified, localization of pulmonary cavities by (Gordon), 274
Rogers, W. L. Discussion of preliminary anterior chondrocostectomy, 563
Rupture of esophagus, spontaneous (Kinsella, Morse, and Hertzog), 613
    report of one case, with recovery (Moore and Murphy), 632

S

Samson, Paul C. Discussion of arteriovenous fistula of lung, 23
  Discussion of resection of pulmonary segments, 478
  (with Dugan, David J.). Strangulation of stomach and traumatic diaphragmatic hernia, 771
Sanger, Paul W. Exploratory thoracotomy in management of pleural empyema, 756
Scannell, J. G. (with Boyden, E. A.). Study of variations of bronchopulmonary segments of right upper lobe, 232
Scapula retractor for thoracoplasty, self-retaining (Brantigan and Aycock), 390
Scott, H. William, Jr. (with Morrow, Andrew G., and Payne, Torrence P. B.). Solitary xanthoma of lung, 821
Shaw, Robert R. Discussion of pulmonary resection for lung abscesses, 532
  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 177
  (with Paulson, Donald L.). Pulmonary resection for chronic abscess of lung, 514
Shefts, Lawrence M. Discussion of arteriovenous fistula of lung, 23
  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 175

Cancer of lung (Neuhof and Aufses), 297

Carcinoma of lower two-thirds of esophagus and cardiac end of stomach (Strieder), 143

  of lung (Adams), 306

Carr, Duane. Discussion of pulmonary resection for lung abscesses, 530

  (with Chandler, Hughes). Dorsal sympathetic ganglionectomy for intractable asthma, 1

  (with Skinner, Edward F., and Denman, William E.). Treatment of inoperable bronchiogenic carcinoma with Methyl-bis, 428

Cassels, Donald E. (with Lawrence, Walter, and Adams, W. E.). Constrictive pericarditis with obstruction of pulmonary veins, 832

Cavity drainage, closed, and posterior thoracoplasty, preliminary anterior chondrocostectomy combined with (Welles and Gordon), 555

Cellulose, oxidized, use of in pleural symphysis (Murphy and McDaniel), 416

Chandler, J. Hughes. Discussion of dorsal sympathetic ganglionectomy for intractable asthma, 1

Chapman, Paul T. (with Day, J. Claude, and O'Brien, E. J.). Closed intrapleural pneumonolysis, 537

Chase, Harold F. (with Mautz, Frederick R., and Beck, Claude S.). Augmented and controlled breathing in transpleural operations, 283

Chondrocostectomy combined with closed cavity drainage and posterior thoracoplasty, preliminary anterior (Welles and Gordon), 555

Chylothorax, traumatic (Lampson), 778

Cinematography, bronchoscopic and esophagoscopic (Holinger, Anison, and Johnston), 178

Circulation, effect of pulmonary inflation and deflation upon (Thompson), 323

Clagett, O. Theron (with Higginson, John F.). Complete disruption of esophagus, 846

Clerf, Louis H. (with Gibbon, John H., Jr., Herbut, Peter A., and DeTuerk, John J.). Diagnosis and operability of bronchiogenic carcinoma, 419

Coarctation of aorta with subclavian-aortic anastomosis, resection of (Bradshaw, O'Neill, and Hightower), 210

Cohn, Bernard N. E. (with Guggenheim, Albert). Contralateral fracture of first and second ribs following thoracoplasty, 366

Collateral ventilation (Baarsma and Dirken), 238

  in man (Baarsma, Dirken, and Huizinga), 252

Contralateral fracture of first and second ribs following thoracoplasty (Guggenheim and Cohn), 366

Crimm, Paul D. Spontaneous collapse, 662

Curreri, Anthony R. Discussion of pulmonary resection for lung abscesses, 533

Cutler, J. W. Pneumonolysis for cure of tension pneumothorax, 374

D

Dailey, James E. Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 173

Daniel, Rollin A., Jr. Regeneration of defects of trachea and bronchi. An experimental study, 335

Davidson, Louis R. Discussion of closed intrapleural pneumonolysis, 552

  Discussion of resection of coarctation of aorta, 221

Davis, Edgar W. Discussion of nonmalignant intrathoracic lesions simulating bronchiogenic carcinoma, 462

Day, J. Claude. Discussion of closed intrapleural pneumonolysis, 553

  (with Chapman, Paul T., and O'Brien, E. J.). Closed intrapleural pneumonolysis, 537

DeBakey, Michael E. Discussion of Methyl-bis for bronchiogenic carcinoma, 437

  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia and tracheoesophageal fistula, 168

  Discussion of symposium on cancer of lung, 316

  (with Ochsner, Alton, Dunlap, Charles E., and Richman, Irving). Primary pulmonary malignancy—factors influencing survival, 573

Decortication of nonexpandable postpneumothorax tuberculous lung (Mulvihill and Klopstock), 723

  spontaneous hemopneumothorax treated by (Elrod and Murphy), 401

Denman, William E. (with Skinner, Edward F., and Carr, Duane). Treatment of inoperable bronchiogenic carcinoma with Methyl-bis, 428

DeStefano, George A. (with Maurer, Elmer). Eosinophilic granuloma of rib, 350

DeTuerk, John J. (with Gibbon, John H., Jr., Clerf, Louis H., and Herbut, Peter A.). Diagnosis and operability of bronchiogenic carcinoma, 419

Diaphragmatic hernia, traumatic strangulation of stomach and (Dugan and Samson), 771

Welles, Edward S. Discussion of closed intrapleural pneumonolysis, 551
Discussion of preliminary anterior chondrocostectomy, 565
(with Gordon, Joseph). Preliminary anterior chondrocostectomy combined with closed cavity drainage and posterior thoracoplasty, 555
Wester, Mary R. (with Norris, Charles, Long, Joan, and Oppenheimer, Morton J.). Bronchospirography: apparatus and technique, 357
Wilson, David A. Extrapleural pneumonolysis with lucite plombage, 111
Wodehouse, G. E. Hemangioma of lung, 408
Woodruff, Warriner. Discussion of preliminary anterior chondrocostectomy, 564
Woods, F. M. Discussion of resection of pulmonary segments, 479
(with Overholt, Richard H., and Betts, Reeve H.). An improved method of resection of pulmonary segments, 464

X

Xanthoma of lung, solitary (Scott, Morrow, and Payne), 821

Y

Yesner, Raymond (with Hurwitz, Alfred). Report of case of localized bronchopulmonary moniliasis successfully treated by surgery, 826

Skinner, Edward F. Discussion of Methyl-bis for bronchiogenic carcinoma, 438
  (with *Carr, Duane, and Denman, William* E.). Treatment of inoperable bronchiogenic carcinoma with Methyl-bis, 428

Smith, David T. Medical treatment of acute and chronic pulmonary abscesses, 72

Solitary lung metastasis, surgical treatment of (Effler and Blades), 27

Sommers, George N. J., Jr. (with O'Brien, Charles E.). War wounds of esophagus, 393

Spontaneous collapse (Crimm), 662

Stephens, H. Brodie. Discussion of esophageal hiatal hernias of short esophagus type, 208
  Discussion of nonspecific suppurative pneumonitis, 512
  Discussion of resection of coarctation of aorta, 221

Stomach and traumatic diaphragmatic hernia, strangulation of (Dugan and Samson), 771
  surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of (Strieder), 143

Strieder, John W. Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac *end of stomach*, 177
  Discussion of symposium on cancer of lung, 319
  Surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach, 143

Sullivan, Herbert. Extrapleural pneumothorax, 38

Swan, Henry (with Mulligan, R. M.). Experimental study of effect of ligation of pulmonary veins in dog, 44

Sweet, Richard H. Discussion of arteriovenous fistula of lung, 23
  Discussion of esophageal hiatal hernias of short esophagus type, 207
  Discussion of nonmalignant intrathoracic lesions simulating bronchiogenic carcinoma, 463
  Discussion of surgical management of carcinoma of lower two-thirds of esophagus and cardiac end of stomach and congenital esophageal atresia *and tracheoesophageal fistula*, 168

T

Thompson, Samuel Alcott. Discussion of effect of pulmonary inflation and deflation upon circulation, 334
  Effect of pulmonary inflation and deflation upon circulation, 323

Thoracic casualties from an island campaign in the Pacific (Raine and Jennison), 91

Thoracoplasty, contralateral fracture of first and second ribs following (Guggen*heim and Cohn*), 360
  posterior, preliminary anterior chondrocostectomy combined with closed cavity drainage and (Welles and Gordon), 555
  self-retaining scapula retractor for (Brantigan), 390

Thoracotomy, exploratory, in management of intrathoracic disease (Grow, Bradford, and Mahon), 480
  of pleural empyema, exploratory (Sanger), 756

Trachea and bronchi, regeneration of defects of; experimental study (Daniel), 335

Tracheoesophageal fistula, congenital esophageal atresia and (Lyon and Johnson), 162
  without esophageal atresia (Haight), 600

Transbronchial spread during lobectomy and pneumonectomy: clinical application, a method of bronchial occlusion for prevention of (Moody), 681

Transpleural operations, augmented and controlled breathing in (Mautz, Beck, and Chase), 283

Traumatic diaphragmatic hernia (Hughes, Kay, Meade, Hudson, and Johnson), 99

Tuberculosis and pregnancy (Johnson, Burch, Bayer, and McClellan), 646

Tuberculous lung, nonexpandable postpneumothorax, decortication of (Mulvihill and Klopstock), 723

V

Vagus nerve section in treatment of peptic ulcer (Weinberg, Campbell, and Voelker), 743

Voelker, Robert B. (with Weinberg, Joseph A., and Campbell, George W.). Vagus nerve section in treatment of peptic ulcer—abdominal versus thoracic approach, 743

W

War wounds of esophagus (Sommer and O'Brien), 393

Waterman, David H. Discussion of nonmalignant intrathoracic lesions simulating bronchiogenic carcinoma, 461
  Discussion of resection of pulmonary segments, 478

Weinberg, Joseph A. (with Campbell, George W., and Voelker, Robert B.). Vagus nerve section in treatment of peptic ulcer—abdominal versus thoracic approach, 743
  (with Kraus, Alvin, and Melnick, Perry J.). Myoblastoma of bronchus, 3[illegible]